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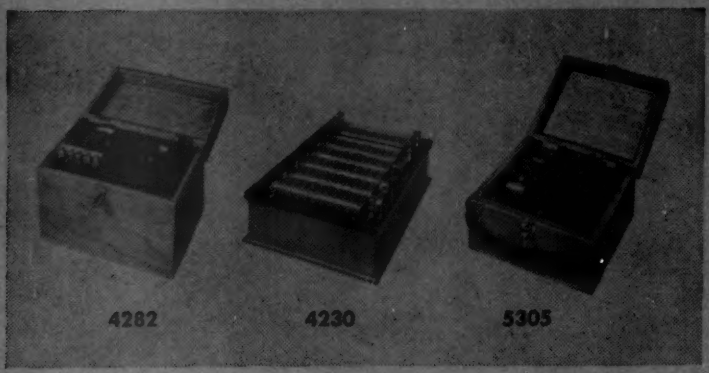

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Enclosed Switch for moderate precision	4760	±0.15%	Seven settings 0.001, 0.01, 0.1, 1, 10, 100, 1000	0 to 9,999 Ω
Post Office Pattern for student instruction	4230	±0.15%	Each has four resistors 1, 10, 100, 1000 Ω†	0 to 11,110 Ω†
Type S-1 Test Set for resistance measurement	5300*	±0.15%	Seven settings, 0.001, 0.01, 0.1, 1, 10, 100, 1000 has provisions for Murry Test‡	9 (1+10+100 +1000) Ω‡
Type S-2 Test Set for resistance measurement	5305*	±0.15%	Seven settings, 0.001, 0.01, 0.1, 1, 10, 100, 1000	9 (1+10+100+ 1000) Ω‡
Ohmmeter for rapid routine testing	4283*	±1%	Slidewire approximately 12" long, calibrated 0 to infinity	1, 10, 100, 1000, 10,000 Ω†
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Type U Test Set for locating cable faults	5430A*	±0.15%	Eight settings, 1/1000, 1/100, 1/10, 1/9, 1/4, 1/1, 10/1, 100/1‡	Four decades 10 (1+10+100)+9 ×1000 Ω† infinity

* Portable self-contained unit, includes battery and galvanometer.
† Plug and block connectors. ‡ Rotary switches.

For more information on Wheatstone bridges send for Catalog E-53, D-C Resistance Measurements.

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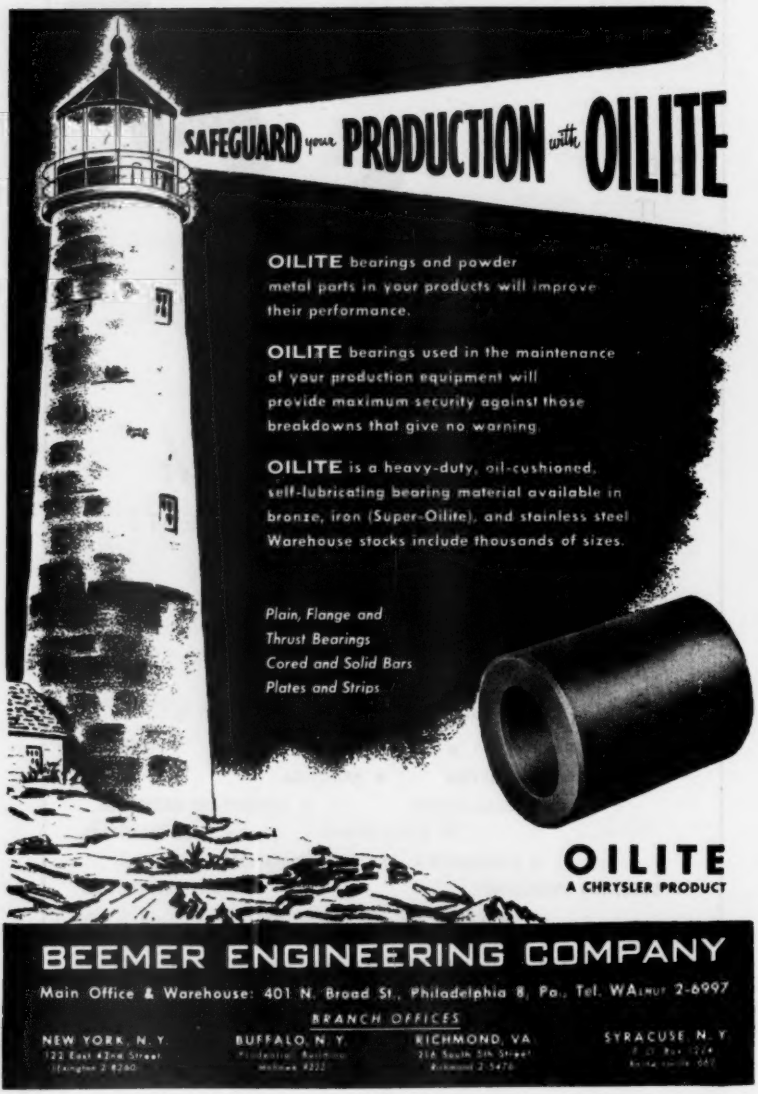
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SELECTION CHART OF ACP PROTECTIVE COATING CHEMICALS FOR STEEL, ZINC, AND ALUMINUM

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STEEL	"GRANODINE" Zinc Phosphate Coating Chemical	Improved paint adhesion	Steel, iron, or zinc fabricated units or components, automobile bodies, refrigerators, washing machines, cabinets, etc., projectiles, rockets, bombs, rifles, small arms, belt links, cartridge tanks, vehicular sheet metal, tank belts and links, recoilless guns, etc.	MIL-S-5002 JAN-C-490, Grade 1 JAN-F-495 U.S.A. 57-0-2, Type II, Class C U.S.A. 51-70-1, Finish 22.02, Class C U.S.A. 50-60-1 16 E4 (Ships)
	"PERMADINE" Zinc Phosphate Coating Chemical	Rust and corrosion prevention	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class B U.S.A. 51-70-1, Finish 22.02, Class B Navy Aeronautical M-364 U.S.A. 72-53 (See An-F-20)
	"THERMOIL-GRANODINE" Manganese-iron Phosphate Coating	Wear-resistance anti-galling, safe break-in of friction or rubbing parts. Rust proofing.	Friction surfaces such as pistons, piston rings, gears, cylinder liners, camshafts, tappets, crankshafts, rocker arms, etc. Small arms, weapon components. Hardware items, etc.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class A U.S.A. 51-70-1, Finish 22.02 Class A Navy Aeronautical M-364 U.S.A. 72-53 (See AN-F-20)
	"GRANODRAW" Zinc-iron Phosphate Coating	Improved drawing, extrusion, and cold forming	Blanks and shells for cold forming, heavy stampings; tubs; tubing for forming or drawing; wire; rod; etc.	———
ALUMINUM	"ALODINE" Protective Coating	Improved paint adhesion and corrosion resistance	Aluminum products of similar design such as refrigerator parts, wall tile, signs, washing machine tubs, etc; aircraft and aircraft parts; bazookas (rocket launchers), helmets, belt buckles, clothes dryers, clothesline, rocket motors, etc., aluminum strip or sheet stock.	MIL-C-5541 (See also QPL-5541-1) MIL-S-5002 AN-F-20 U.S. Navord O.S. 675 16 E4 (Ships) AN-C-170 (See MIL-C-5541) U.S.A. 72-53 (See AN-F-20)
ZINC	"LITHOFORM" Zinc Phosphate Coating Chemical	Improved paint adhesion	Zinc alloy die castings; zinc or cadmium plated sheet or components; hot dip galvanized stock; galvanneal; signs; siding; roofing; galvanized truck bodies; etc.	QQ-P-416 RR-C-82 JAN-F-495 AN-F-20 U.S.N. Appendix 6 U.S.A. 72-53 (See AN-F-20)

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Journal
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Vol. 253 FEBRUARY, 1952 No. 2

PICTORIAL RADIO

BY

C. D. TUSKA [1]

Part II [2]

Rice High Frequency System for Locating Objects (1936)

Although Chester W. Rice's system resembles Gutton's, we shall find several differences. Such differences, as well as detailed information, may be found in Rice's U. S. Patent 2,412,631 (17)[3]. The following is based upon the patent specification and drawings.

Rice was concerned with a positive indication of the position of an object, its motion, and its velocity. He concluded that if radio waves followed optical laws of reflection, practically all of the energy impinging on an object would travel in a direction determined by the angles of incidence and reflection. However, using very short wave lengths upon an irregular surface, the waves would scatter in all directions about the point of impingement in accordance with a cosine law. If the wave length was short compared to the irregularities, substantial amounts would be reflected toward the point of origin of the waves. He preferred that the wave length should not be less than 2 cm. because of the scattering by raindrops or hailstones, or longer than 8 cm. because of the dimensions of the wave reflecting surfaces of aircraft and vessels. Rice states that he obtained extremely satisfactory results with waves having a length of 4.8 cm.

Details of Rice's apparatus are illustrated by the drawings. Figure 27, corresponding to Fig. 1 of the patent, shows a transmitter 1 and a

[1] Director of Patent Department, Radio Corporation of America, RCA Laboratories Division, Princeton, N. J.

[2] Part I appeared in this JOURNAL for January 1952, p. 1.

[3] The boldface numbers in parentheses refer to the references appended to both parts of this paper.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

receiver 2 tiltably mounted on a supporting member 19. The supporting member is secured to a shaft 4 that may be moved back and forth by a motor 15, gear 16 and crank 17. The entire mechanism is carried by a head 5 and a shaft 6 that may be rotated in a base 3 by a motor 12 and connecting gears 13 and 14. Brushes and slip rings 36 through 45 are used to convey power and signals to and from the rotating apparatus.

The transmitter 1 includes a high frequency generator and antenna which are located within a compartment 22, cylindrical housing 25 and parabolic reflector 24. The receiver 2, which is capable of receiving the reflected high frequency waves, includes an antenna located within

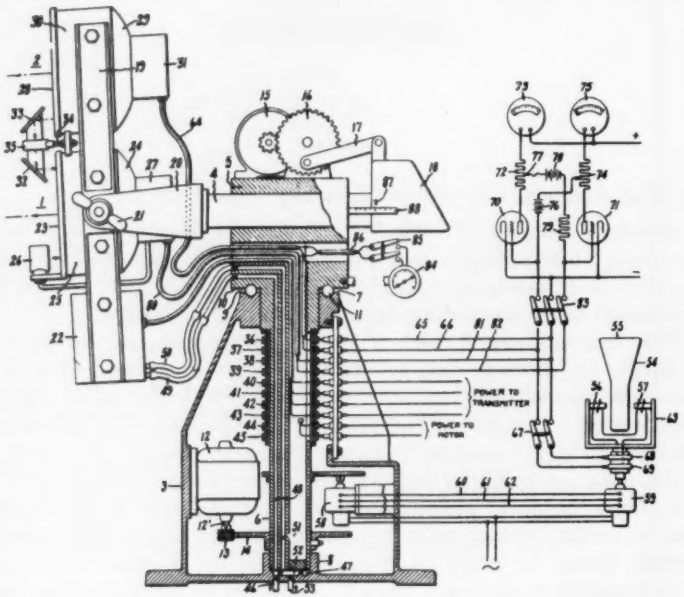

FIG. 27.

the housing 28 cylindrical sleeve 30 and parabolic reflector 29. The controlling apparatus is housed within the compartment 31 located at the rear of the reflector 29. Both the transmitter and receiver are highly directional.

The transmitter is monitored by a small receiver 26 mounted near the lower portion of the housing 25. A small portion of the wave from the transmitter 1 is passed directly to the receiver 2 by a pair of small reflectors 32, 33 that are mounted on an adjustable rod 34. The phase of the wave is determined by adjusting the path length; the intensity is controlled by a metal iris diaphragm 35.

The path of the reflected waves is indicated on a cathode ray tube 54. The cathode ray is deflected radially by deflection coils 56 and 57. The deflection coils 56 and 57 are mounted on a yoke 63 which

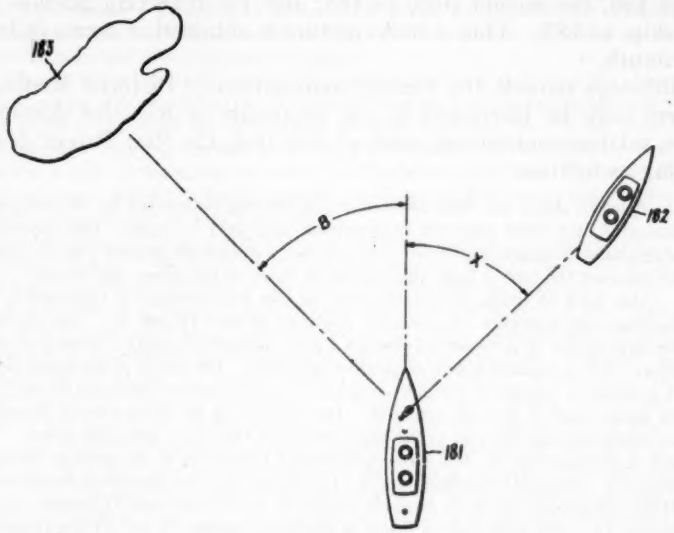

FIG. 28.

is rotated in synchronism with the shaft 6 by repeater devices 58 and 59. As the transmitter beam is rotated in azimuth, the cathode ray is rotated to provide a continuous circular trace. Signal currents, derived from the reflected waves, are applied to the deflection coils to deflect the ray along a radial path.

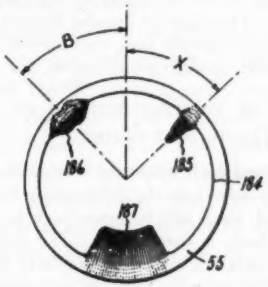

FIG. 29.

Figure 28 (Fig. 4 of Rice Patent) illustrates the application of the system carried by a ship 181. In front of the ship are two objects: one is an island 183 and the other a second ship 182. The bearing of

the island is B with reference to the ship's course. The bearing of the second ship is X with reference to the course. The reflected wave signals are graphically shown in Fig. 29. The island is shown as image 186; the second ship, as 185; and the reflecting portion of the first ship, as 187. Thus a radio picture is obtained in terms of bearing or azimuth.

Although outside the formal boundaries of "Pictorial Radio," the readers may be interested in the proposals of Rice for determining range, relative motion and sense of direction, the Rice Patent describes ranging as follows:

> After an object has been detected and its bearing determined by the radio echo apparatus, it is often desirable to determine accurately its range. One method of determining the range of an object is to transmit a sharp high frequency radio impulse and measure the time it takes the impulse to travel to the object and return.
>
> One form of timing circuit for effecting this measurement is indicated in the drawings and comprises two electron discharge devices 70 and 71. The anode of discharge device 70 is connected through a potentiometer 72, and a current indicating device 73 to a suitable source of positive potential. The anode of discharge device 71 is similarly connected through a resistor 74 and a current indicating device 75 to the same source of positive potential. The cathodes of discharge devices 70 and 71 are connected together and to the negative side of the above potential source. The grid of discharge device 70 is connected through battery 76 to the plate of discharge device 71. The grid of discharge device 71 is connected to the plate of discharge device 70 through potentiometer 72, movable contact 77 of potentiometer 72, battery 78 and resistor 79. The grids and cathodes of discharge devices 70 and 71 are connected to the apparatus associated with receiver 2 and transmitter 1, respectively.
>
> If a negative impulse be impressed on the grid of discharge device 71 each time a sharp high frequency impulse is propagated from transmitter 1 and if a negative impulse be impressed on the grid of discharge device 70 each time the reflected impulse is detected by receiver 2, the average plate current flowing through either discharge device will be a function of the range of the object which causes scattering or reflection of the transmitted impulse. The negative impulse derived from the propagated high frequency wave is obtained from a small monitor receiver 26 and its associated apparatus housed in compartment 27 through cable 80, slip rings 38 and 39, conductors 81 and 82, and switch 83. . . . The negative impulse derived from the received reflected impulse is similarly obtained from the apparatus housed in compartment 31 through cable 64, slip rings 36 and 37, conductors 65 and 66, and switch 83.

The determination of relative motion or velocity is based upon Doppler's principle. The patent states:

> . . . a highly directional high frequency continuous radio wave is propagated from one body toward the other and the difference in frequency between the transmitted wave and received wave which comes back to the first body after being scattered by the second body is determined. The fact that there is a difference in frequency between the outgoing and returning wave is due to the relative motion between the two bodies. According to Doppler's principle the difference in frequency between the transmitted and received wave is a function of the relative velocity of the two bodies. The method of determining the difference in frequency between the transmitted and received wave . . . comprises beating the received wave with a portion of the transmitted wave.
>
> In Fig. 1 of the drawings I have indicated at 84 a beat frequency responsive

device, mounted on bearing member 5. This device is connected to the receiver 2 through a switch 85, cable 86, and cable 64.

A portion of the high frequency wave propagated from transmitter 1 and reflected into receiver 2 by reflectors 32 and 33 is caused to beat with the detected scattered radiation. It will be understood that beat frequency responsive device 84 may be calibrated directly in miles per hour.

Although the velocity of a moving object along the line of sight from the object to the receiving equipment may be determined from the beat frequency responsive device 84, it is impossible by this method alone to determine whether the object is moving away from the observer or coming towards him. By providing a pointer 87 on the portion of the apparatus which is adapted to be oscillated by motor 15 and by securing a scale 88 on bearing member 5, a means for determining the direction of motion along the line of sight is provided.

The direction of motion of ship 182 along the line of sight is . . . determined by energizing motor 15. The oscillatory motion of transmitter 1 and receiver 2 along the line of sight causes an oscillation of the pointer on beat frequency responsive device 84 due to the fact that the point with reference to which the velocity of the distant object is to be determined is no longer stationary.[4] If the object, whose direction of motion is to be determined, be moving away from the apparatus a minimum of frequency occurs during the forward motion of the apparatus. If the object be moving toward the observer, a maximum of frequency occurs during the forward motion of the apparatus. If the object be standing still the frequency is the same during each direction of the motion of the apparatus. The presence of the beat note, in any case, of course, indicates the presence of the object in the path of the radiated waves. Thus, by watching pointer 87 which indicates the oscillatory motion of transmitter 1 and receiver 2 and by watching the pointer on beat frequency responsive device 84 the direction of motion of ship 182 along the line of sight is determined.

Moulinier French Patent 813,404 (1936)

Gabriel Moulinier's French Patent 813,404 (**18**) describes a system for determining graphically the azimuth, elevation, distance, and speed of an object reflecting radio waves. Figures 30 and 31, corresponding to modified Figs. 1 and 2 of the patent, illustrate the directive antennas and features of the apparatus.

As shown in Fig. 30, highly directive antennas 2 and 3 are mounted on a shaft 4. This shaft moves the antennas about a horizontal axis when the shaft is actuated by the worm and gear that are driven by a motor 9. The antennas may also be rotated about a vertical axis which includes the rotatable shaft 1. The vertical shaft is rotated by a second motor 10 and connected worm and gear drive.

A stylus 7, moving in synchronism with horizontal movements of the antennas and cooperating with chemically treated paper, is used to record graphically indications of the elevation of a wave reflecting object. A second stylus 8, operating in a similar manner and in synchronism with the vertical axis, records azimuth. Details of the mechanically and electrical arrangement of the antennas, rotating mechanism and recording devices are not shown or described in the patent.

[4] Rice apparently assumes that vessel 181 carrying the apparatus is stationary.

Some of the circuitry is found in Fig. 31. Ultra-high frequency currents from an oscillator 12 are applied to the transmitter antenna radiator 14 which is positioned within the reflector 3. The high frequency currents establish a sharply directed beam 33. The beam after reflection arrives along the path 34 and induces signal currents in the collector 16 of the antenna 2. The signal currents are detected by a receiving tube 11. The detected signals are amplified 20 and are

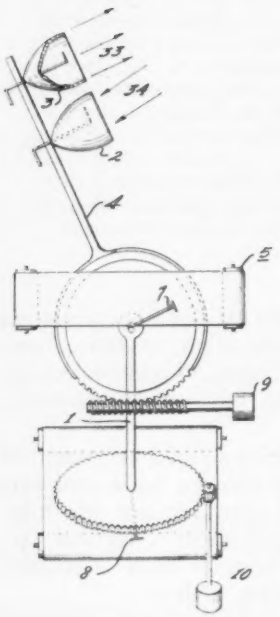

FIG. 30.

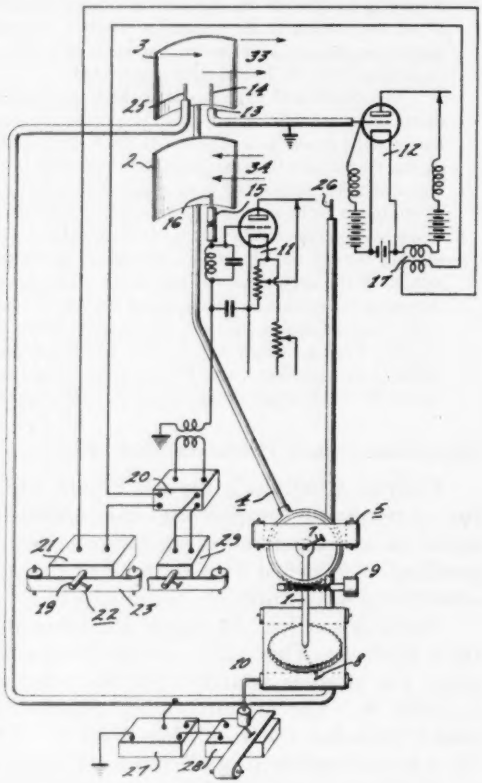

FIG. 31.

applied through a transformer 17 to modulate the oscillator 12. The amplified currents are also applied to the styli 7 and 8. The currents through their respective styli react on the chemically treated recording paper. Thus the reflected signals are recorded to indicate the azimuth and elevation of the wave reflecting object.

Distance to the reflecting object is determined by the modulation frequency. Since the modulation rate is dependent upon the time taken for the waves to travel to the object and back, it follows that

the longer the distance, the longer the time and therefore the lower the frequency. Conversely, if the round trip time is short, the modulation period will be short and therefore the modulation frequency will be higher. Moulinier proposed to measure the modulation frequency by means of the meter 21. The frequency or distance may be recorded on the tape 23 by currents applied to the stylus 22. The distances are thus determined and are indicated by graphic recording similar to that used for recording azimuth and elevation.

The rate of motion of the obstacle may be determined by comparing the frequency of outgoing waves with the frequency of the incoming reflected waves. Currents including the two frequencies may be derived from the main antennas or separate antennas 25 and 26 may be used. The comparison circuits include an amplifier 27 and a frequency meter and recorder 28 for the separate antennas and circuits, or the frequency responsive device and stylus recorder, indicated by the numeral 29 of the main apparatus, may be used.

Lyman Tridimensional Radio Direction Indicator (1937)

A "tridimensional" radio indicator is described in Joseph Lyman's U. S. Patent 2,231,929 (19). The indicator may be used in aircraft to prevent collisions, for locating aircraft, or for directing aircraft landings from the ground. While the Lyman device provides two coordinate information, in the author's opinion the third coordinate is an inference of the observer rather than a real measured coordinate. Before considering this question, the indicator will be described by referring to Figs. 32 and 33, (corresponding to Figs. 2 and 3 of the Lyman Patent).

The antenna scanning apparatus of Fig. 32 is mounted on the nose of an aircraft. The balance of the apparatus may be located within the aircraft. The receiving antennas 3 and 5 are arranged to scan in horizontal and vertical planes with reference to the fore and aft axis of the craft. The scanning is accomplished by rotating the parabolic reflectors 2 and 4 by means of gearing 7 and 9 and shafts 6 connected to a motor 8. The vertical scanning is thirty times faster than the horizontal scanning. The shaft of the horizontal reflector 2 is connected by gearing and a shaft 9 to the rotatable arm 10 of a potentiometer 11. The motor shaft 8′ is likewise connected to the rotatable arm 21 of a potentiometer 27. The potentiometers are connected to horizontal 16 and vertical 17 deflecting electrodes of a cathode ray tube 18.

Currents are generated at a frequency of approximately 600 megacycles per second by the transmitter 96. These ultra-high frequency currents are applied to an antenna 97. The radiations from the antenna are sharply focused by a reflector 98. The reflector 98 is rotated in synchronism with the receiving antenna reflector 2 and in the same phase position. Although not shown, a second antenna and a second

reflector are arranged to operate in synchronism and in phase position with the vertical scanning reflector 4.

Signals from the transmitting antenna after reflection are impressed on the receiving antennas. The received signals are applied through the transformer 35, 36, 37 to a detector and audio amplifier 38. The amplified signals are impressed on a grid controlled rectifier 48. The rectifier is normally biased to be inoperative in the absence of the maximum signals from the two receiving antennas. When the maximum signals are received simultaneously, a positive bias is applied to the cathode ray tube control electrode 28. Thus the cathode ray beam, which is normally biased off is permitted to pass through the focusing and deflecting electrodes to the fluorescent screen 39.

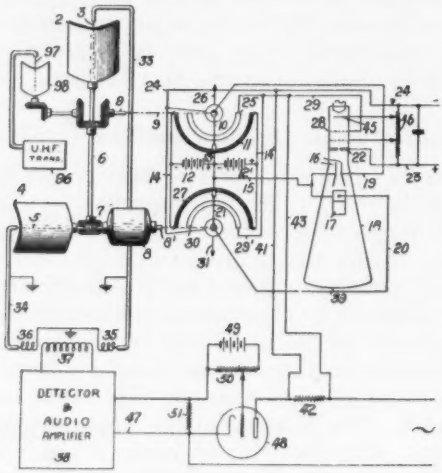

FIG. 32.

The potentiometers, operating in synchronism with the antennas, apply deflecting potentials to the deflecting electrodes to move the beam horizontally and vertically to positions corresponding to the instantaneous positions of the receiving antenna beams. Shorting contacts 25, 26, 30, 31 also operate in synchronism with the reflectors and short circuit the resistor 42 during the undesired or rearward 180° of reflector rotation.

The result of the operation is to deflect the ray along the vertical broken lines 40, as shown in Fig. 33, thirty times for each horizontal deflection. Actually the ray does not leave a trace in the absence of the simultaneous application of the reflected signals. When the signals are applied, the ray strikes the screen and causes the fluorescent indication 46. The position of the indication or spot 46 with respect to the horizontal and vertical guide lines 53 and 54 indicates the position

of the reflecting object with reference to the longitudinal axis of the aircraft. The circle 52 on the screen is to indicate the danger zone.

The patent states: "Collision is to be expected when the spot of light remains within the circle and gets larger, or when the spot 46 remains still in any position on the screen while getting larger." The foregoing statement might be true if the reflecting surface maintains a constant angular relation to the planes or lines of reference or a constant degree of reflectivity. However, if the angular position should change, the amplitude of the reflected signal, and hence size of spot, might decrease instead of increase. For example, suppose that reflections are obtained from a flat surface 50 ft. in diameter disposed normal

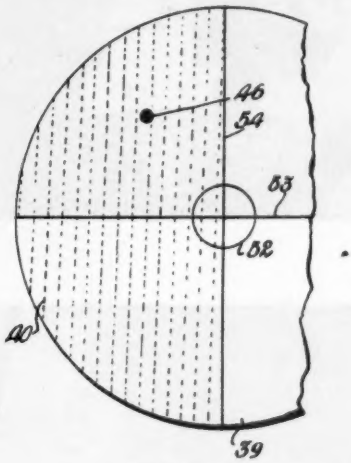

FIG. 33.

to the aircraft course and at a distance of 5000 ft. If the surface is rotated through an angle of 60° or more while the distance is decreased to 3000 ft., it seems clear that the spot size will decrease instead of increase. Under some conditions an observer might infer distance from spot size.

Wolff Radio Vision (1935–1938)

After the demonstrations of 1934, Irving Wolff and his RCA associates adopted "radio vision" as their goal (12). In 1937 they demonstrated a modified microwave system. The carrier frequency was the same as that employed in their 1934 tests but was pulsed. The pulse duration was less than a microsecond. Because of the short pulse, distances could be indicated to within 5 ft. The system included a magnetron transmitter, and a special magnetron detector of the superregenerative type.

FIG. 35.

FIG. 34.

The transmitter and receiver were installed on the roof of the RCA Laboratory in Camden, Figs. 34 and 35. The Philadelphia skyline, about two miles distant, and ships in the Delaware River were scanned by the pulsed transmitter beam. The reflected pulses were received, amplified, and applied to a cathode ray indicator. One coordinate of the indicator corresponded to distance; the other coordinate corresponded to angle. Thus an area picture was created by radio vision.

Although other developments intervened, this seems to be an appropriate place to discuss Wolff's three coordinate radio vision inventions on which patents have now issued in Belgium (20), Italy (21) and Spain (22). One method of adding the third coordinate is to view an image of a two coordinate radio vision picture in a mirror that oscillates in

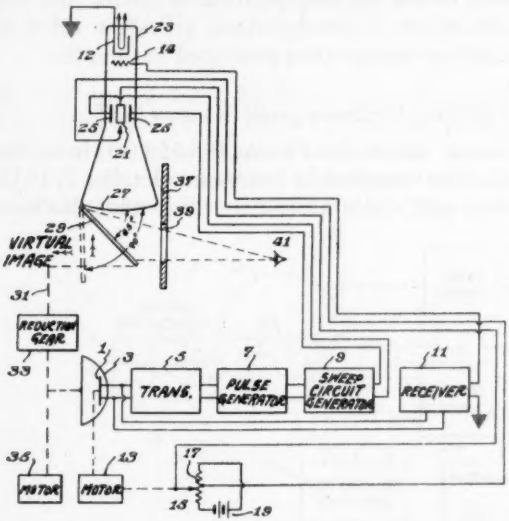

FIG. 36.

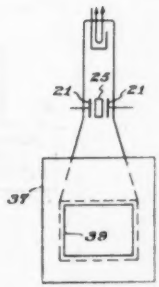

FIG. 37.

synchronism with the radio wave scanning beam as shown in Figs. 36 and 37. The radio portion of the device includes an antenna 1 positioned at the focus of a reflector 3. The antenna is energized by a transmitter 5 that is keyed by a pulse generator 7. The pulse generator and a sweep circuit generator 9 are synchronized. The sweep generator output is impressed on the deflecting electrodes 25 of a cathode ray indicator tube 23.

A radio receiver 11 is also connected to the antenna 3. The output of the receiver is applied to the grid 14 of the cathode ray tube. The antenna and reflector are oscillated about their vertical axis by a motor 13. Biasing potentials, corresponding to antenna position, are derived from a potentiometer 17, and are applied to a second pair of deflecting electrodes 21 in the cathode ray tube.

Thus far the illustrated system involves a radio vision picture in which distance is represented as a coordinate parallel to the lines of the page. The second or angle coordinate is at right angles to the plane of the page. The picture appears on the fluorescent screen 27 of the cathode ray tube. A third coordinate is produced by viewing the picture in a mirror 29. The mirror is oscillated about a 45° position in synchronism with the beam from the antenna. The directive antenna and the beam therefrom are oscillated through the desired angle of elevation by a motor 35. The motor also drives the mirror through a reduction gear 31.

An image of the fluorescent screen appears in the mirror. The image is viewed through an aperture 39 in the mask 37. The location of the image, with reference to the angular position of mirror and the radio beam with which the mirror is synchronized, gives the third or vertical coordinate. The picture image thus produced has depth.

Gloess Sounding Devices Utilizing Electromagnetic Waves (1937)

Paul Francois Marie Gloess' Australian Patent 108,556 (**23**) indicates that a corresponding application was filed in France on October 2, 1937. In addition to a description of a radio altimeter, the patent discloses

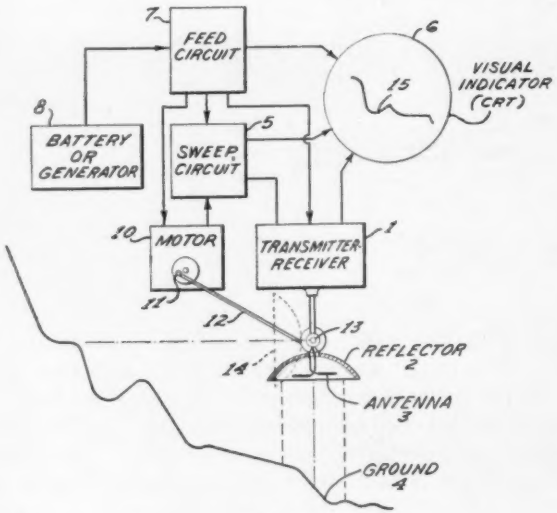

FIG. 38.

a radio contour determining instrument. The contour of the surface in front of and beneath an airplane is determined in terms of angle and distance.

An ultra-short wave transmitter-receiver 1 of Fig. 38 is connected

to an antenna 3 positioned in the reflector 2. The beam is moved between the ground and the region in front of the craft. The movement is accomplished as follows: the reflector and antenna are connected to an eccentric 11 by a connecting rod 12. The eccentric is driven by a motor 10. Power is supplied by a generator 8 through a feed circuit

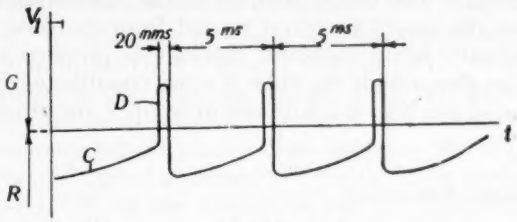

FIG. 39.

box 7 to the motor. Power is also applied to a sweep circuit 5, the transmitter-receiver 1, and a cathode ray tube 6.

The wave form of the sweep circuit output potential is shown in Fig. 39. The transmitter is energized by the pulses *D*. The pulse duration is 20 milli-micro-seconds. The receiver is powered during

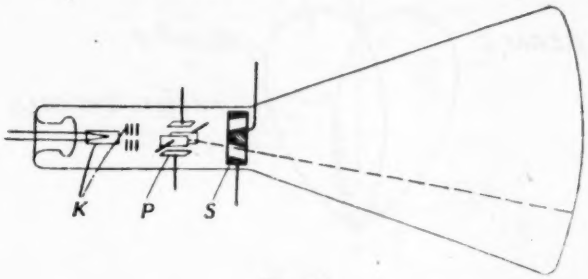

FIG. 40.

the 5 microsecond periods *C*. The cathode ray is moved radially by applying sawtooth potentials to the radial deflecting electrode S of Fig. 40. The ray is also swept along a circular path by applying the quadrature currents, illustrated in Fig. 41, to the pairs of deflecting electrodes *P* in the cathode ray tube. The quadrature currents are

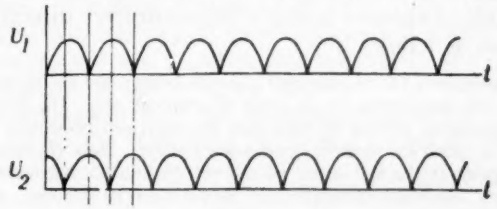

FIG. 41.

synchronized with the motor 10 which, through the eccentric and rod, causes the radio beam to oscillate between its vertical and horizontal positions. The cathode ray beam is biased off in the absence of reflected waves but is biased on by the reception of the reflected waves.

The angular position of the cathode ray corresponds to the ultra-short wave beam. The radial position of the ray corresponds to the time taken for the waves to travel to and from the reflecting object. The wave velocity being constant, distance is proportional to time. The trace 15 on the cathode ray tube is a two coordinate representation of the contour of the land 4 below and in front of the aircraft carrying the device.

Radar Directional Indication

The designers of graphic radar devices soon realized that in addition to indicating the distance or range of a wave reflecting object, something should be done to indicate the precise direction of the object. By using centimeter wave lengths, narrow beams were created and usable

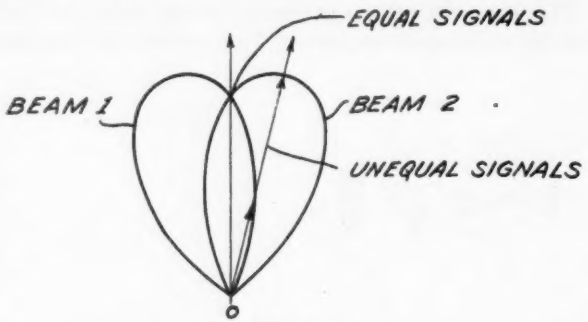

FIG. 42.

directional information was obtained. Nevertheless, in the 1930's short waves meant low power and low range. High power and longer range were obtainable at longer wave lengths. However, longer waves meant complicated and massive antenna systems and even then the beam widths were excessive for many applications.

Major General Coulton (13), in his article in the *Proceedings of the Institute of Radio Engineers* states a representative directivity problem and its solution as follows:

> The difficulty was that a sufficiently narrow beam could not be produced at a frequency of 110 megacycles, by an array of practical size. The direction of the target was obtained by moving the beam past the target and attempting to determine the direction at which the received signal was strongest. Since the beam was broad (20 to 30 degrees at the half-power points) the direction of maximum signal was correspondingly imprecise, generally not better than 10 degrees. The military requirement was for angular precision of 1 degree or better.

The clue to the answer was found in the "A-N" radio range beacon, [24] used in navigating aircraft, developed by Lieutenant Colonel Murphy at the Signal Corps Aircraft Radio Laboratory. In this system, a precise path is found by overlapping two broad beams and following a path in the overlap region where the two beams have equal strength. The general principle is illustrated in Fig. 13. [Figure 42 in this text.]

Hershberger Range and Directional Indicator (1938)

William D. Hershberger proposed a system with graphical directional indication in his U. S. Patent 2,189,549 (25). As shown in Fig. 43, corresponding to Fig. 5 of the patent, a pair of rhombic antennas 41 and 43 are used to direct radio frequency wave beams on alternate sides of a reference line or plane. The reference line may correspond to the longitudinal axis of an aircraft, if the device is used as a collision warning system. If on the first cycle the left antenna 41 is short-

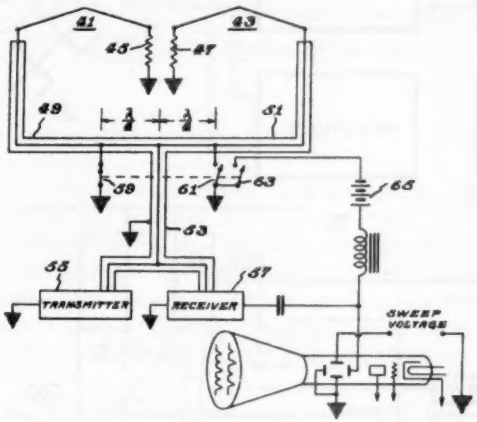

FIG. 43.

circuited by the switch 59, the right antenna will be energized. On the next cycle the right antenna 43 may be short-circuited by the switch 61, and the left antenna energized. Thus the left and right antennas are alternately energized by the pulse transmitter 55 to establish "left-right" overlapping beams.

The receiver 57, keyed on after the transmitter, responds to the reflected pulses. The received signals are applied to a cathode ray tube indicator. The cathode ray is swept alternately along two distance scales by a sweep voltage. Deflections normal to the distance scales indicate the ranges of the reflected objects. The distance scales are selected in synchronism with the antenna energization by switching a bias voltage 65 to the deflecting electrodes to which the signals are applied. Thus graphic indications of direction, for example left and right, are obtained along with range information.

Wolff Radio Locator (1939)

While the Hershberger device could be used to locate objects with reference to a pair of intersecting planes, the observer of the graphically displayed information might have some difficulty in rapid interpretation. Irving Wolff in his U. S. Patents 2,412,702 and 2,412,703 (26) describes a radar system with graphic indications of distance and direction in three coordinates. Figures 44, 45, and 46 correspond respectively to Figs. 1, 3 and 4 of the Wolff '703 Patent.

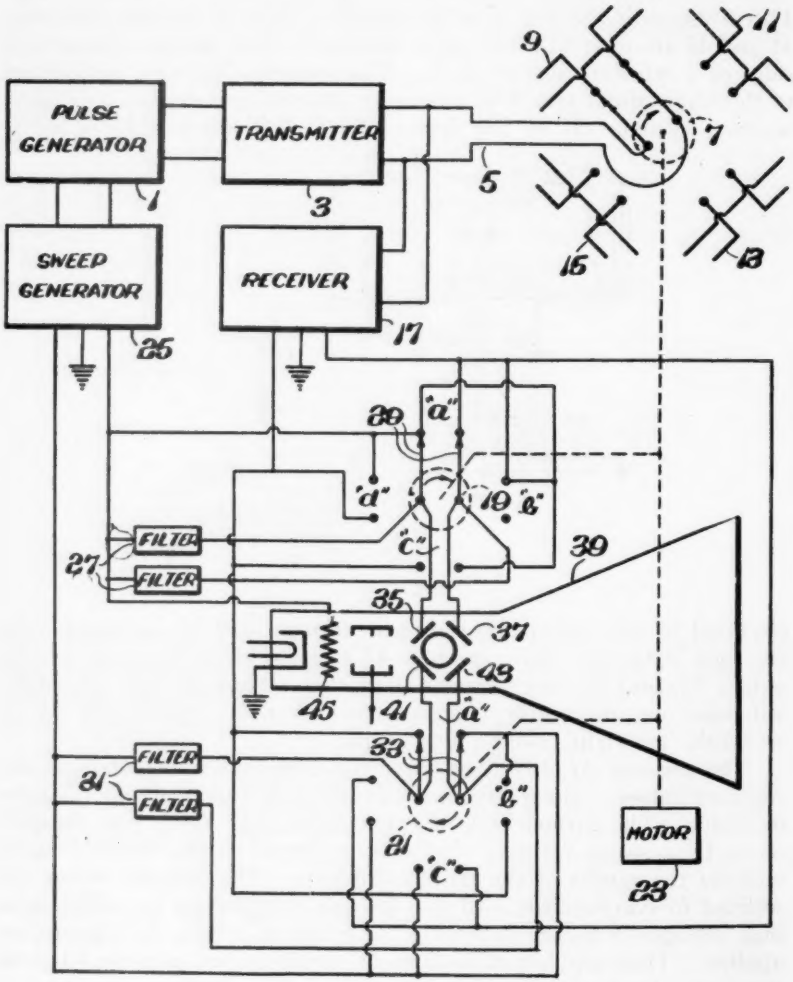

FIG. 44.

A pulse generator 1 modulates the transmitter 3 which successively energizes four directional antennas 9, 11, 13 and 15. The resulting radiation patterns overlap as shown in Fig. 46. The pulse generator 1 and the sweep generator 25 are synchronized so that for each outgoing pulse, sweep potentials are applied between deflecting electrodes 35 and 37, and 41 and 43. Ordinarily the deflecting electrodes of a cathode ray tube are energized as oppositely disposed pairs. In the present case pairs of two adjacent electrodes are energized to provide

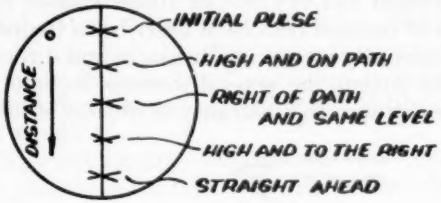

FIG. 45.

diagonal deflection of the cathode ray beam. The diagonal deflection corresponds to distance as shown in Fig. 45.

The received reflected signals from the successive zones of radiation are applied through the receiver 17 to four distinctive combinations of the deflecting electrodes by the switches 19 and 21. These switches are driven in synchronism with the antenna switch 7 by a motor 23. The application of the received signals produces a deflection that is angularly disposed with reference to the distance sweep and is distinctively positioned to correspond to the zone of reflection.

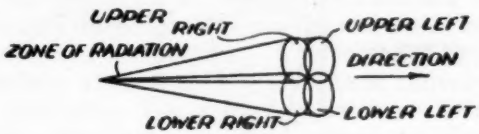

FIG. 46.

The graphical display indicates the location of the object with respect to intersecting reference planes or reference path in the following manner: The unreflected initial pulse results in equal signals in all zones. Therefore, the angular deflections are equal and symmetrical and are at 0 distance. If the upper pair of signal indicating deflections are equal and are greater than the lower pair of deflections, the reflecting object is high and on path and at the distance indicated by the position of the deflections on the distance scale. If the signals produce greater angular deflections to the right than to the left but equal deflections to the right, then the reflecting object is at the level of the reference path but to the right of the path and at the distance shown. In other

words, the magnitude of the respective reflected signal indicates the zonal location of the wave reflecting object. And at the same time distance is shown by the position of the angular deflections along the distance scale.

Rost and Claesson Apparatus for Simultaneously Measuring Distances and Directions of Invisible Objects from a Movable or Stationary Spot (1939)

The British Patent 542,643 (27) of Helge Fabian Rost and Harry Elias Claesson is of interest because it describes a frequency modulated device for simultaneously measuring distances and directions. In Figs. 1, 2 and 3 of the patent the several systems include indicators that show the average distance to a plurality of objects of increasing heights

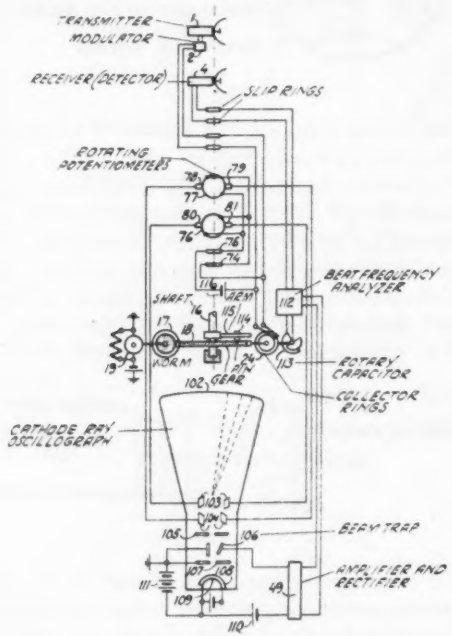

FIG. 47.

disposed along the same radial direction. However, here we shall consider in Fig. 47 (Fig. 4 of the patent) the system in which a plurality of reflections from objects in the same radial line may be indicated simultaneously.

A frequency modulated transmitter 1 with its beam antenna is mounted on a shaft 16. A receiver 4 with its antenna is also mounted on the shaft. The shaft is oscillated through a desired angle by means

of a slotted arm 115 that engages a pin 114 attached to a gear 18. The gear 18 is driven by a worm 17 that is attached to a motor 19. The motor also drives a single phase converter, represented by collector rings 24, and the variable capacitor 113 of a beat frequency analyzer 112.

Currents from the converter are applied (*a*) to the pair of potentiometers 76 and 77 and (*b*) to the modulator 2. Currents from a battery 116 are also applied to the potentiometers. Voltages derived from the sliding contacts of the potentiometers are applied to the deflecting electrodes 103 and 104 of the cathode ray tube. Since the potentiometers are fixed to the shaft 16, they move in synchronism with the antennas and provide an instantaneous voltage to deflect the cathode ray beam in a direction corresponding to the path of the frequency modulated radio waves.

The alternating currents from the converter are combined with the direct current to produce minimum deflecting potentials for the lowest modulation frequency and the maximum deflecting potential for the highest modulating potential. Thus the cathode ray beam is deflected radially to correspond to distance. The use of the common converter synchronizes the transmitter modulation with the radial position of the cathode ray beam with zero modulation and zero distance being at the center of the fluorescent screen 102.

Some of the outgoing signal energy reaches the receiver directly to beat with the incoming reflected signals. The difference or beat frequency is proportional to the time taken for the waves to travel to a reflecting object and return. Since the wave velocity is constant, travel time is proportional to distance. The beat frequency currents are applied to the analyzer 112. The rotary capacitor 113, operating in synchronism with the transmitter modulation, passes beat frequency signals to the amplifier and rectifier. The amplified signals overcome the bias of a battery 110 and thereby permit the cathode ray beam to pass the beam trap 106. The beam then impinges on the fluorescent screen to indicate simultaneously the distances and directions of the radio wave reflecting objects. In the absence of reflected signals the beam trap deflects the beam to a beam trap diaphragm 105 instead of the fluorescent screen.

Zworykin and Vance Radio Gunfire Control (1941)

Before considering some of the pictorial radio developments of World War II, attention is directed to the Radio Gunfire Control of Vladimir K. Zworykin and Arthur W. Vance U. S. Patent 2,409,462 (**28**). The patentees proposed to provide simultaneous radar indications of the placing of shots with reference to a target and to control the fire as a function of the radar information.

Figure 48 (Fig. 1 of the Patent) illustrates a pair of radio (radar)

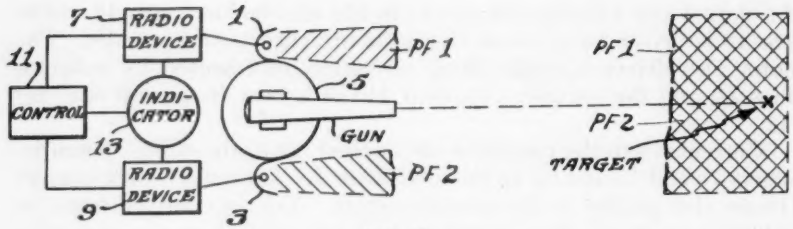

FIG. 48.

devices 7 and 9 that are connected to directive antennas 1 and 3. The radar devices are also connected to an indicator 13 and to a control 11. The antennas may be fixed to the gun 5. The radio beams PF1 and PF2 from the antennas overlap at the target *X*. A comparison of the amplitudes of the received signals indicates the direction of the target while the range scale indicates the distance of the target.

The method of operation as described in the patent is as follows:

> Distinctive pulses F1 and F2 of radio frequency energy are radiated by the radiators 1, 3 to form overlapping patterns PF1 and PF2. The region of equal field strength is arranged to coincide with the normal trajectory of shells fired from the gun. The outgoing pulses are reflected by the target. The reflected pulses are received and applied to the indicator. The indicator shows initially two things: first, the range of the target, and, second, whether the target is to the right or left of the normal trajectory. This information is obtained, as will hereinafter be explained, by observing the relative amplitudes of the pulses reflected by the target along the two patterns PF1 and PF2.
>
> The gun is elevated to correspond to the indicated range and the turret and directive radiators are synchronously rotated until the cathode ray tube indications show that the gun is centered on the target. The nature of the centering indications are shown in Figure 49A. The sharply defined pulse P indicates the range or distance of the target and the tilting of the pulse indicates that the region of equal signal strength of the patterns PF1, PF2 is not centered on the target. When the patterns are properly centered, the pulse will be perpendicular to the range scale.
>
> After the gun has been thus directed, the directive radio devices are preferably locked in position and a shell is fired. The effects accompanying the shell hit, the

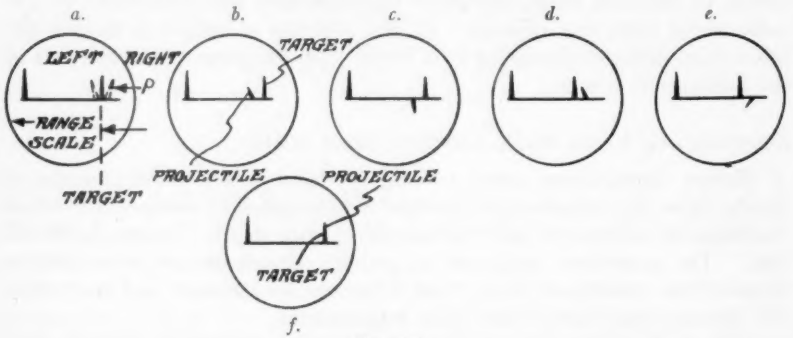

FIG. 49.

bursting of the shell, or its splash if fired into the sea, (if within the region of either or both of said radiation patterns) will cause the radio pulses to be reflected. The reflections will be indicated as to left or right or short or over the target, depending upon the position of the burst with respect to the target. The possible indications are as follows: Figure 49B short and left; Figure 49C short and right; Figure 49D over and left; Figure 49E over and right; and Figure 49F on the target. For any particular indication, the gun is "over-corrected" and additional shots fired until a bracket is established according to conventional gunfire methods. The bracket is indicated visually as functions of the propagation time and relative amplitudes of the pulses reflected by the shell effect in its final position.

The apparatus is described in the patent by reference to Fig. 2 (here Fig. 50). The desired shell burst indications are produced by

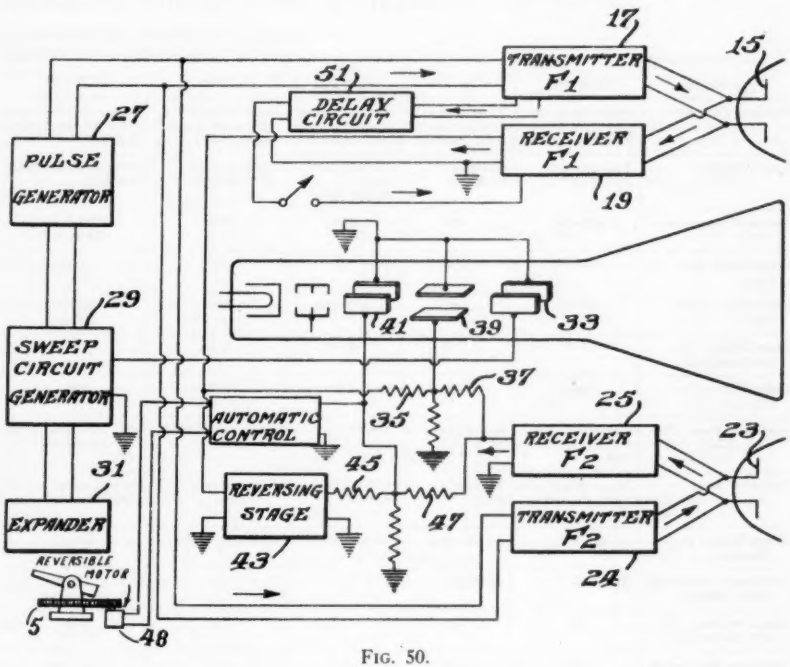

FIG. 50.

the inclusion of an extra pair of deflecting electrodes in the cathode ray tube. The extra electrodes are connected in networks that are shown in Fig. 50. Reference is made to the patent for a more detailed description.

WAR AND POSTWAR PERIODS

Military radar of the early type described by General Coulton (13) was available at the beginning of World War II. Because radar was recognized as an important weapon scientists, engineers, and research workers were called upon to develop many different types of radar to

meet anticipated military needs. By way of example of the war period developments, Fig. 51 (*a*), (*b*) and (*c*) illustrate three different methods of scanning regions to be searched. In the radar devices the

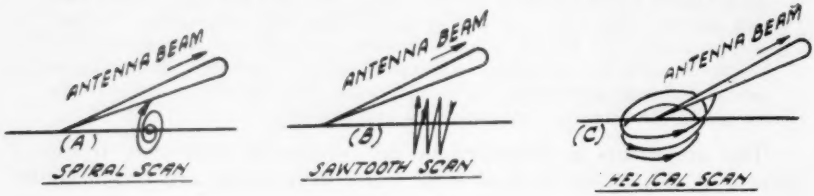

FIG. 51.

TABLE I.—*Technical Specifications of*

Type Number	SCR-268	SCR-516	SCR-270	AN/TPS-3	SCR-545
Primary Function	Searchlight and gun control (mobile)	Early warning against aircraft (mobile)	Early warning against aircraft (mobile)	Light weight for search and tracking (mobile)	Search (s) and track (t) for AA fire-control (mobile)
Size, Weight	Two trailers; 28,850 lb.	Same as SCR-268	3 trucks and trailer; 81,400 lb.	Air-transportable; 1340 lb.	2 trucks and trailer; 71,460 lb.
Carrier Frequency (mc.)	195–215	205	110	600	205 (s) 3000 (t)
Wavelength (λ) (cm.)	140–154	146	270	50	146 (s) 10 (t)
Peak Power (P_t) (kw.)	50–75	100	100–300	200	200 (s) 350 (t)
Pulse Width (d) (microseconds)	5–9	5–8	10–30	1.5	1
Pulse Rate (f_r) (pps.)	4098	1366	621	200	480
Radiator Type, Size, Gain (G_0)	Three mattresses; 100	Same as SCR-268	4×9 mattress; 140	10-ft. paraboloid; 220	4×4 mattress (s) 60; 57-in. parab. (t) 1300
Types of Scan	Manual track in azimuth and elev.	Manual search	Circular search	Circular search	Helical search, conical track
Beam Width (b) (degrees)	12 az., 9 el.	12 az., 9 el.	28 az., 10 el.	12.5 az., 11.5 el.	25 (s) 5 (t)
Horizontal Scanning Rate (rpm.)	Manual	Manual	1	6	5
Receiver Noise (n) (db above $kt\Delta f$)	14	14	12	11	7 (s) 22 (t)
Receiver Bandwidth (Δf) (mc.)	1.5	1.5	1.5	1.8	1.25 (s) 5 (t)
Indicators	3 type-A	3 type-A	1 type-A	1 type-A, 1 type-PPI	3 type-A
Maximum Range (r_{max}) on Bombers at 10,000 Feet (miles)	23	68	80–120	100	34 (s) 16 (t)
Minimum Range (yd.)	3000	3000	10,000	10,000	1100 (s) 500 (t)
Range Accuracy (yd.)	200	500	8000	4000	150 (s) 15 (t)
Angular Accuracy (degrees)	1.1	3	4	2	6 (s) 0.17 (t)

beam reflecting targets could be pictorially presented by an appropriate one of six different types of cathode ray displays as shown in Fig. 52. The last four types are especially within the writer's definition of pictorial radio.

The nature of the task that confronted those responsible for the development can be gleaned from the papers published in the *Proceedings of the Institute of Radio Engineers* by Edwin G. Schneider (**29**) on "Radar" and Lloyd V. Berkner (**30**) on "Naval Airborne Radar." The performance specifications of ten of the Signal Corps radars published in *Electronics* (**31**), November 1945, are reprinted in Table I through the courtesy of the McGraw-Hill Publishing Co.

Representative Signal Corps Radars.

SCR-547	SCR-582/682	SCR-584/784	AN/TPL-1	AN/MPG-1
Range finder for AA fire-control (mobile)	Coastal search for ships and planes (fixed)	Search (s) and automatic track (t) for AA fire-control (mobile)	Light weight searchlight (mobile)	Seacoast fire-control against marine targets (mobile)
2 trucks and trailer; 49,487 lb.	3359 lb. (582); 13,640 lb. (682)	Trailer, 20,000 lb. (584); 12,000 lb. (784)	Trailer; 4205 lb.	Trailer; 28,000 lb.
2720–2890	2800	2700–2900	2700–2900	10,000
10	10.7	10–11	10–11	3
80	30 (582) 225 (682)	300	200	60
0.5	1	0.8	1	1 (s) 0.25 (t)
4098	500 (582) 420 (682)	1707	400	1024 (s) 4098 (t)
2 57-inch parab.; 5000	4-ft paraboloid; 800–900	6-ft paraboloid; offset dipole; 1200	4-ft. paraboloid; 860	Schwarzschild rapid-scanner; 12,000
Range only, optical tracking	Circular search	Helical search, conical track	Helical search, conical track	Circular search; also 10° sector; track
3.8	6	4 (7 when spinning)	10	0.6 az., 3 el.
Manual	10–20	6	7.25	160°/sec
—	18 (582) 14 (682)	15	18.5	17
6	1.5 (582) 2 (682)	1.7	1.8	10
1 type-A	1 type-A 1 type-PPI	2 type-J 1 type-PPI	3 type-A 1 type-PPI	2 type-B 1 type-PPI
12	45 (582) 140 (682)	34 (s) 18 (t)	34	28 (battleship)
300	1000 (582) 500 (682)	500	500	—
25	2 per cent	15	200	—
—	2	1 (s) 0.06 (t)	1 (s) 0.5 (t)	—

Thus the wartime radar devices were designed to search the sea, the land, and the air for information not ordinarily visible. Not only were invisible targets made visible but tracking means were employed to follow a selected target automatically without human aid (**31**, **32**). Airborne radar made night bombing and bombing through an overcast practical. Winston Churchill (**33**), who was one of the best qualified to see the over-all pattern of World War II, gives radar great credit in his account published in the *New York Times* in the fall of 1950.

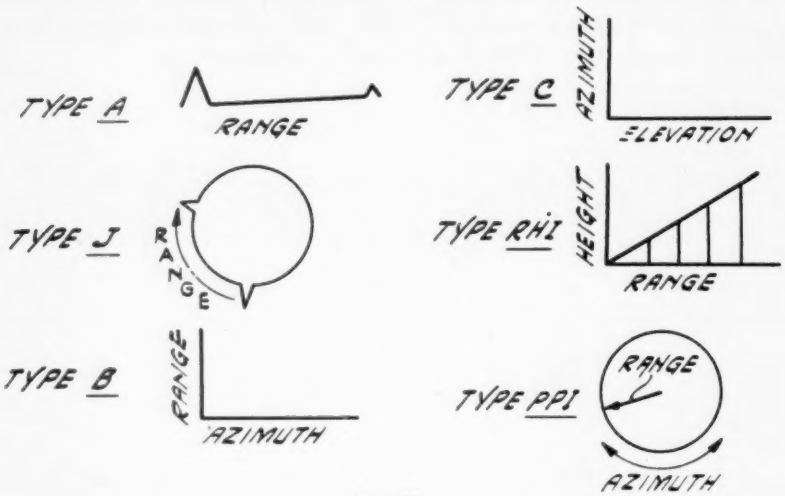

FIG. 52.

Radar Gun Fire Control

An excellent report of gun fire control by radar is given in the following account in Jennings B. Dow's (**32**) "Navy Radio and Electronics During World War II," reprinted here through the courtesy of the Institute of Radio Engineers.

> I shall quote a few extracts from an action report by the Commanding Officer of a light cruiser to illustrate by example the degree of importance of radar. Any one of hundreds of other equally impressive reports by commanders of ships and aircraft units might be quoted for this purpose. This particular report covers an engagement between opposing cruiser forces. The times designated are local civil times.
>
> "2200: conducting continuous search through 360 degrees with search and fire-control radars.
>
> "2338: made radar contact with a group of objects bearing 295 true distance about 14,000 yards. Checked with navigator to insure that contact was not land.
>
> "2339: radar plot reported contact as 5 ships bearing 065 relative and 295 true, range 13,300 yards. Set condition affirm with guns loaded.
>
> "2342: main battery was laid on, and tracked target showing largest radar impulse, believed to be leading enemy cruiser. Starboard antiaircraft battery was on second target from left of a group of three ships. These were believed to be

screening destroyers, ahead of the cruisers. Course and speed of both targets 140 true, 26 knots.

"During tracking phase, our van destroyers were known to be coming up on the starboard quarter en route to their position in the van. However, the continous radar track of the approaching enemy force was completely distinct from the tracks of own ships.

"2346: commenced firing with both batteries immediately following the next cruiser astern. The main battery concentrated with the cruiser astern on leading enemy heavy ship, in continuous fire, using radar train and ranges. Hits were observed in the first salvo, which was a short straddle. Fire was maintained, with a spot of up 100, and in a relatively short time the target was lighted up by a fire amidships. She was tentatively identified by several officers as a heavy cruiser. Our gunfire was apparently very effective at this short range, and the target was hit almost continuously. At about 2350 the enemy sank, going down by the bow, with her screws still turning, and her turrets apparently still trained in.

"The antiaircraft battery opened fire on the center smaller ship in the enemy van, bearing slightly to the left of the main battery target. Fire control was with radar ranging and training, and shortly after fire opened, splashes were observed on either side of the target ship in the range notch. About 2350 the target disappeared from both screens, leaving own splashes still showing. Reports from other stations indicated that this target was a destroyer, which broke in two and sank.

"2351: during this period we fired with both batteries on a target, believed to be another destroyer, in the vicinity of the first antiaircraft battery target. 'Cease firing' was ordered when an explosion was observed on the target, and it disappeared from the radar screens. At least three enemy ships were observed on fire in the target area at this time.

"2353: commenced firing at a ship to the right of previous target. Firing was at full radar control without illumination. Fires breaking out on the bow of this ship illuminated her midsection for a short time. She was observed to be a two-stack cruiser with trunk forward of stack and latticed tripod mast close to after stack. This ship was returning our fire. Some damage was sustained from the fire of this ship but radar continued to function satisfactorily.

"2359: fires were observed burning on an enemy destroyer. This ship fired on her for two minutes in radar control. Hits were observed. 'Cease firing' was ordered when target disappeared from radar screen at 0001."

From what I have quoted, it will be noted that two Japanese cruisers and two destroyers were disposed of in a period of 15 minutes during darkness. I leave to your own imagination the chaos which must have existed in this Japanese force which, in the darkness of night and without apparent knowledge or warning, suddenly found itself caught in the devastation of fire of our own ships. I leave also to your imagination the tremendous importance of radar to the successful outcome of this and many similar sea engagements.

Postwar PPI Radar

As is frequently the case, tools of war are quickly adapted to postwar use. The Governments of the United States and Great Britain, respectively, suggested marine radar specifications to provide a "starting point." These and other requirements were carefully analyzed by Irving F. Byrnes (34) in his paper "Merchant Marine Radar," published in the *RCA Review*, March 1946. The Byrnes article includes many engineering considerations, and the following performance table (reprinted by courtesy of *RCA Review*) which illustrates the keenness of radar vision:

Object (Target)	*Average Range (Nautical Miles)*
High coast lines (300 ft. or more)	20 to 50
Low coast lines (30 ft. or more)	5 to 10
Average cargo ship (400 ft. long)	7 to 10
Small fishing vessel (40 ft. long)	2 to 5
Average buoy (metal)	1 to 5

A radar for the merchant marine service is described in detail by Frank E. Spaulding, Jr. (35) in the June, 1947 issue of the *RCA Review*. The indicator unit, antenna assembly, and transmitter-receiver unit are shown in Fig. 53. A close-up of the indicator, control panel and 12-in. PPI scope appears in Fig. 54. The performance features are here reprinted through the courtesy of *RCA Review*.

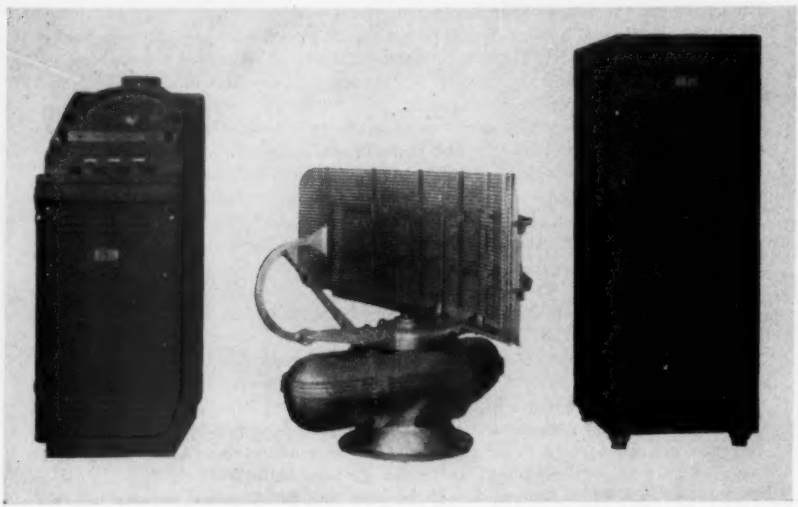

FIG. 53. Indicator, antenna assembly, and transmitter-receiver.

Frequency:	9320—9430 megacycles. Magnetron center frequency = 9375 megacycles (3.20 centimeters).
Transmitter Peak Power Output:	30 kilowatts from Type 725-A tube.
Range Scales:	0–1½; 0–5; 0–15; 0–50 miles, with calibration in nautical or statute miles.
Range Rings:	1½ mile range...3 rings— ½ mile apart. 5 mile range...5 rings— 1 mile apart. 15 mile range...3 rings— 5 miles apart. 50 mile range...5 rings—10 miles apart.
Pulse Length:	½ microsecond on 1½ and 5 mile ranges. 1 microsecond on 15 and 50 mile ranges.
Pulse Repetition Rate:	3000 cycles per second on 1½ and 5 mile range. 750 cycles per second on 15 and 50 mile range.
Duty Cycle:	0.00075 on all ranges.

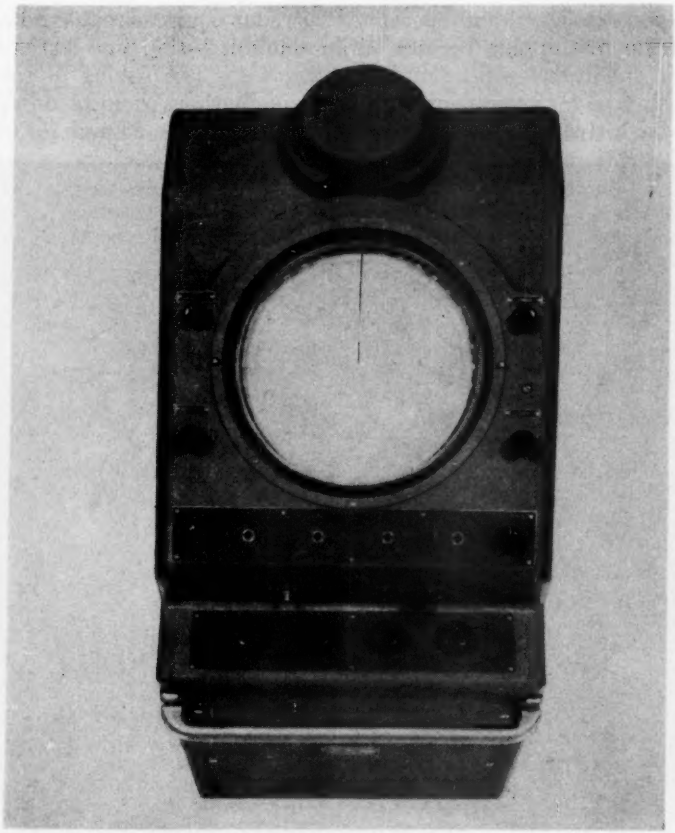

FIG. 54. Closeup of indicator unit, control panel and 12-in. PPI.

Heading Flash:	This electronic marker shows ships heading (brightness of flash adjustable).
Range Markers:	± 2 per cent or 100 yards (whichever is greater).
Range Resolution:	Capable of showing two visible objects as two distinct images if they are separated by 80 yards in range with the radar operating on the shortest range scale.
Bearing Resolution:	Approximately 3 degrees or less.
Bearing Accuracy:	Less than 2 degrees error between antenna and indicator.
Display:	PPI display on 12-inch cathode-ray tube.
Azimuth Scales:	Fixed illuminated scale—11½ inches in diameter—1 degree marks. Movable illuminated scale 10½ inches in diameter—1 degree marks.
Bearing Cursor:	Adjustable cursor line for measuring bearing of targets.

Properly designed and operated PPI radar equipments have been a great boon to shipping because radar minimizes the time lost due to weather conditions which hinder navigation. The saving of time is especially true for vessels entering or leaving harbors or ports, or traveling through rivers, or restricted waterways (see Figs. 55 and 56).

FIG. 55. PPI photograph showing ship approaching Belle Isle at Detroit. (1½ mile range; range rings are ½ mile apart.) Compare this picture with Fig. 56 which shows a map of this area.

PPI Radar in Navigation

C. J. Pannill (36) in his article "Ship Radar Tested" provides the following account of PPI radar as it was actually used in navigation on the Great Lakes. It is reprinted through the courtesy of *Radio Age*.

> Several dramatic instances have occurred to illustrate the effectiveness of this electronic aid to navigation. In mid-October it enabled the 614-foot *Ferbert* to negotiate the winding channel of the 22-mile St. Mary's River, which connects Lakes Superior and Huron, through a peasoup fog which immobilized 60 other vessels for more than 14 hours. Approaching the southern entrance to the St. Mary's channel about 5 a.m., at the height of the fog, Captain Frank Davenport of the *Ferbert* observed on the indicator scope of his radar that the shores of the river were lined with

fog-bound ships at anchor. Relying entirely upon the radar picture, he was reported able to see the positions of other ships as precisely as in normal weather. None of the other ships was able to proceed until after the fog lifted. The *Ferbert* not only saved more than eight hours by not waiting for the fog to lift, but gained additional time by passing through the Soo locks ahead of the 60 other vessels. The following day, the Detroit District Office of the War Department Corps of Engineers reported that the *Ferbert's* comparatively rapid progress through the hazardous channel had alarmed other shipmasters who did not know that the vessel was guided by radar.

FIG. 56. Map of area shown in Fig. 55.

On one of the *Ferbert's* last voyages before traffic on the Great Lakes was suspended for the winter, this Radiomarine radar played a vital role in the prevention of a near tragedy. This happened during a blinding snowstorm on Lake Superior, just before dawn on November 28. The *Ferbert* was running eastward toward Sault Ste. Marie, about 12 miles above the northernmost tip of the upper Michigan peninsula. First Mate Tom Hermansen was watching the radar image when he observed that the luminous "pips" representing two other ships were rapidly converging from opposite direction—racing toward a head-on collision. Realizing that lookouts on neither vessel could see the other ship in the snowstorm, Hermansen immediately contacted the two ships by radio, warned them of their danger, and directed each on a change of course which averted the collision. The two vessels were the *SS J. H. Sheadle* and the *SS Sascatu*, and it was reported later that the officers of both vessels had been unaware of their danger until they were warned by Hermansen.

As this storm continued after dawn, the *Ferbert* with her radar was reported to be the only vessel able to navigate with certainty, and her officers repeatedly received

radio calls from other ships requesting information on their position in relation to other shipping and the shore. This performance of the three-centimeter radar in the snowstorm was significant evidence of the suitability of the ultra-high-frequency equipment for use in merchant marine navigation.

Merchant marine radar Type PPI has been so successful that beginning in 1946 and up to October 4, 1950, approximately 1,100 United States vessels were equipped with commercial radar units. Some 600 vessels of the United Kingdom registry were fitted with radar and approximately 500 ships of other foreign countries are known to have radar installations. (37). Thus the wartime development of pictorial radio has become a truly great postwar blessing.

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A PROPOSED MUSICAL NOTATION

BY

PARRY MOON [1]

ABSTRACT

Description is given of a new musical notation which eliminates the traditional clefs, key signatures, and accidentals. A 6-line staff is employed, with each semitone on a separate line or space. A duodecimal specification replaces the customary alphabetical and sol-fa designations of pitch.

The immediate purpose of the new notation is to facilitate the thinking of composers, arrangers, and music students. Eventually, however, some such reform seems inevitable also in printed music.

1. INTRODUCTION

Musical notation, after a development lasting a thousand years, finally reached a form which has not changed appreciably since the 18th century. The notation is based on the diatonic scale, particularly the scale of C major. If this scale were always employed, the present notation might be almost ideal. But even in the time of Schubert, frequent modulations covered the score with accidentals; and with the advent of atonal and other modern music, the old notation has become almost hopeless.

Today, many musicians realize that traditional nomenclature is inadequate for modern needs. As P. A. Scholes says,[2] "A glance at a page from, say, a later work of Scriabin or Schönberg should be convincing to any musician who maintains that the present notation is 'good enough.' It is certainly not 'good enough,' and just as the Spelling Reformers maintain that the adoption of the reform would 'save a year of school life,' and the advocates of the metric system that the adoption of their reform would do the same, so the inventor of any reasonably thought-out reformed staff notation can claim that he is offering the means of saving several years of music study."

A number of modified notations have been proposed, including those of Thomas Salmon (1672), H. O. Anderton (1893), A. Vinée (1909), Manuel Guérvos, W. H. Thelwall, André Piaceski, Pierre Hans, John Stéphan, Arnold Schönberg, C. Pot, and Nicholas Obouhow. In general, however, the suggested changes seem to complicate rather than to simplify things. The present paper suggests another possible notation, obtained by applying a procedure that has been successful in developing scientific nomenclature for physics and mathematics.

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[2] P. A. SCHOLES, *The Oxford Companion to Music*, Oxford University Press, 1943, p. 621.

2. REQUIREMENTS

What is the purpose of a musical score? Evidently its primary function is to transmit the composer's wishes to the instrumentalist or vocalist who produces the musical tones. A musical note may be characterized physically by four factors: fundamental frequency, duration, intensity, and quality. Composers ordinarily make no attempt at quantitative specification of the third and fourth factors—beyond such vague directions as *forte, piano, crescendo, sul ponticello, con sordino*, the details of interpretation are left to the artist. Thus a musical score deals primarily with frequency and duration: *it is essentially a graph of frequency vs time.* As soon as one realizes this funda-

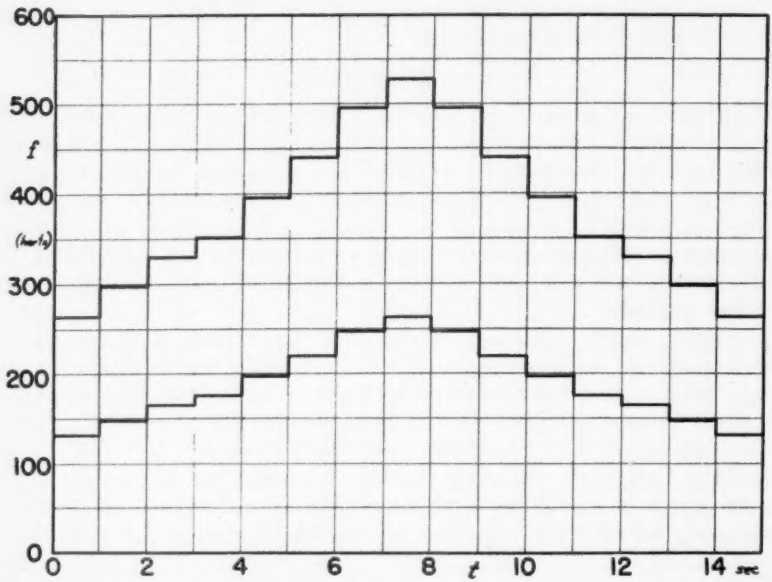

FIG. 1. Scale of C major, played in octaves with tempered intonation and $a' = 440$ hertz.

mental fact, he sees that the problem of musical notation is merely the problem of finding the most convenient way of presenting a frequency-time graph.

The physicist would, of course, employ an ordinary plot of f vs t. For example, Fig. 1 shows the specification for a C-major scale played in octaves on a piano tuned in the tempered scale with $a' = 440$ hertz (cycles per second) and in 4/4 time with ♩ = 60. Such a graph would not satisfy a musician. In one way it specifies too much, in another way it does not say enough. The composer has no desire to specify absolute frequencies or even to indicate whether the tempered scale or some other scale is to be used. He knows that in the production of

sustained chords with non-keyboard instruments, competent musicians will make the necessary pitch adjustments so that the chords are true; and he knows that in melodic passages, the intonation will be such as produces an artistic result. So *a pitch specification to less than a semitone is not needed in the ordinary musical score.*

On the other hand, Fig. 1 does not make immediately evident the fact that the right and left hands are playing the same scale. Any system of musical notation must conform to the psychophysiological requirement that a given frequency ratio be recognized as the same, irrespective of absolute frequency. A frequency ratio of 2:1 is always recognized by our auditory nervous system as an octave, a ratio of 3:2 is always recognized as a perfect fifth; and a satisfactory notation should represent such musical intervals by fixed distances along a vertical scale. Thus the frequency specification must be on a logarithmic basis.

The foregoing considerations indicate that an ideal musical notation should satisfy the following requirements:

1. The vertical scale must be proportional to $\log f$, so that a given musical *interval* is always represented by the same vertical distance, regardless of position on the scale.
2. The horizontal scale must be linear in time, or essentially so.
3. Pitch specification to less than a semitone is not required.
4. A 1:1 correspondence must exist between pitch[3] and notation. That is, a given position on the vertical scale must correspond to one and only one definite semitone; and a given semitone must be representable in only one way. The latter requirement is violated by the traditional notation, where 35 different symbols are used to represent the 12 semitones in an octave. *This is not simplicity.*
5. The unique psychophysiological aspect of the octave must be incorporated in the notation. Two notes differing by one or more octaves must be immediately recognizable as the same note. This means the abolition of the F, G, and C clefs.
6. Key signatures should be omitted. They are unnecessary and introduce needless complexity.

The customary musical notation violates all six requirements. A system that satisfies the criteria is presented in the next section.

3. THE NEW NOTATION

The proposed notation is indicated in Fig. 2. A 6-line staff is employed, covering exactly one octave, with D on bottom and top

[3] For simplicity, the word "pitch" is used in this paper to designate a *physical* quantity associated with frequency. The Acoustical Society of America prefers to reserve "pitch" for the *sensation*, with the physical specification designated as "logarithmic frequency level" or some such term. Perhaps a better word could be found—for instance oros (Gk ὄρος) which suggests height or change of level—but the use of "pitch" for a physical concept will probably cause no confusion in this paper.

lines. The lines of the staff correspond to a pentatonic scale. The middle lines, A and G, divide the octave into fourths and fifths, while the C and E lines are each two semitones from D. The other notes of the chromatic scale are on spaces, as indicated by the small divisions of the vertical scale. Thus E♭ is represented by a note in the space between the E and D lines, while A♭ is midway between the A and G lines. F is above E by one-third the distance between E and G, while

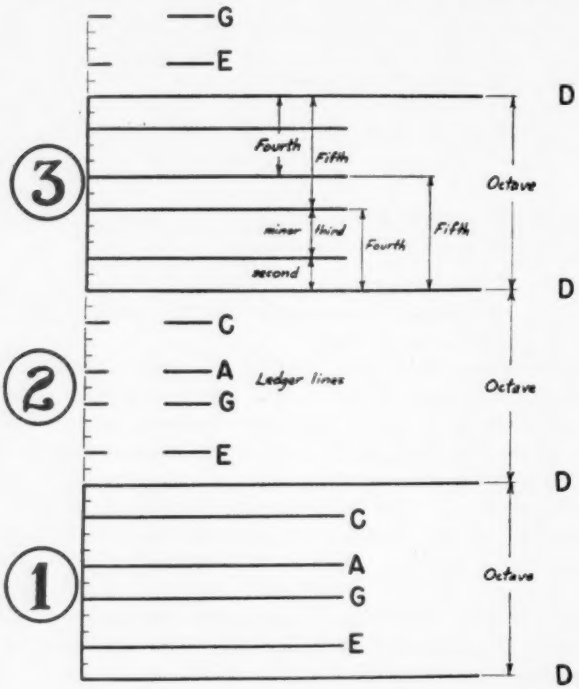

FIG. 2. Proposed 6-line staff. Each small division of the vertical scale represents a semitone. By allowing a separate vertical position for each semitone, we eliminate all key signatures and all accidentals. The staves are always the same, with D on top and bottom lines. The octaves are designated by a circled number. The total range shown in the diagram is from D below the bass clef to A above the treble clef. Middle C is on the first ledger line below No. 3 staff.

F♯ is two-thirds this distance above E. Evidently the vertical scale is a measure of log f and is a true representation of musical pitch.[3] Unlike the old staff, the new arrangement has a distinct position for each semitone and thus eliminates the need for sharps and flats.

The staves can be piled on top of each other in any way that is convenient. Bass and treble clefs are not used. Instead, each octave is designated by a number which appears in a circle to the left of its

staff. In Fig. 2, the staves for octaves 1 and 3 are drawn in, while notes in octave 2 are identified by means of ledger lines between the two staves. Ledger lines may also be employed above staff 3 and below staff 1. In all cases, lines are spaced exactly as in the staff, with intervals of 2, 3, 2, 3, 2 semitones.

The arrangement of Fig. 2 corresponds roughly to the familiar bass and treble clefs of piano music. The C that is ordinarily written two lines below the bass-clef staff would appear in Fig. 2 on the ledger line directly below staff 1; while middle C would be one line below staff 3, and the third line of the treble clef would become the top line of staff 3.

The system is flexible, Fig. 2 being only one possible arrangement. In vocal quartet music, for instance, only staves 2 and 3 are needed and they may be separated by any convenient distance. In instrumental

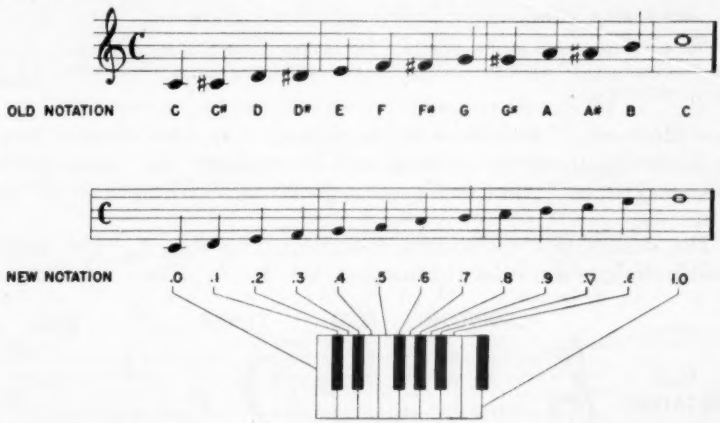

FIG. 3. A chromatic scale in old and new notations. The notes may be designated by numbers in the duodecimal system and are read "point zero" (C), "point one" (C♯), . . . "point nine" (A), "point dec" (A♯), "point elf" (B).

music, frequent change of octave may be desirable. Such a change can be obtained at any place by merely inserting a circled number to indicate that the octave has shifted. Incidentally, this designation of the octave has the advantage that a mistake in playing will hardly be noticed; while with the old system, a pianist who forgets that the left hand is supposed to be in the treble clef, or a 'cellist who mistakes the treble for the tenor clef, produces havoc.

The lines of the staff are, of course, added to the log f-scale merely to aid the musician in reading the notes. A 6-line staff is not mandatory. Various staves, ranging from 2-line to 12-line, were tried in the new system but the 6-line staff appeared to be the best. The choice of D for upper and lower lines gives a pleasingly symmetrical arrangement. It also puts all the open strings of the violin family on lines.

Figure 3 shows how a chromatic scale appears in the new notation.

No sharps and flats are present, and there is no embarrassing question about whether one should write A♯ or B♭. The notes may still be called by their old names, but a more advantageous way is to number the semitones, beginning with .0 at C. In place of C, then, we read "point zero," for C♯ we read "point one," for D "point two," etc.
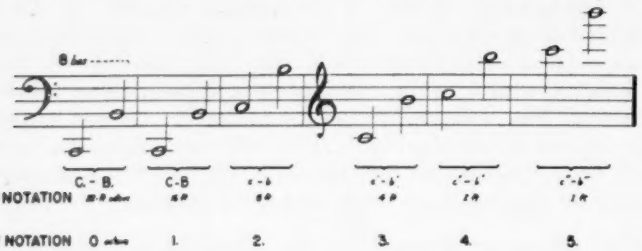
FIG. 4. Designation of the octaves. The octave is specified by a number to the left of the "decimal point," while the position of a note within the octave is specified by a number after the point (Fig. 3).

Since there are 12 semitones in the octave, it is convenient to employ the duodecimal number system[4] and to represent the tenth semitone (A♯) by .∇ (read "point dec") and the eleventh (B) by .ε (read "point elf").

The designation of octaves is indicated in Fig. 4. The simplest possible designation is by the integers 0, 1, 2,.... The contraoctave or
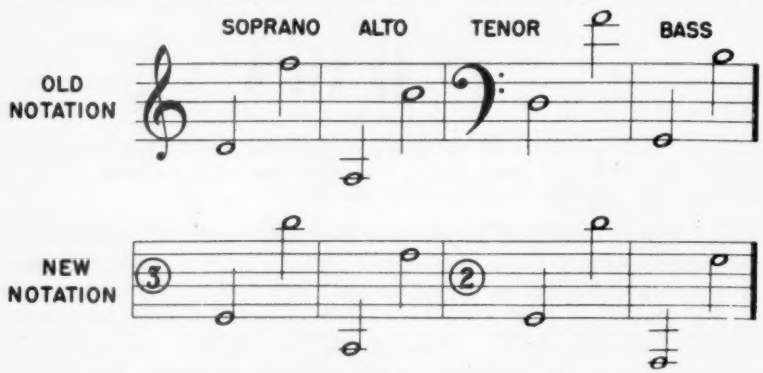
FIG. 5. Approximate voice ranges, expressed in old and new notations.

32-ft. octave is specified in the new system by 0., the great octave or 16-ft. octave is called 1., and so on. Higher octaves than those of Fig. 4 are designated as 6., 7.,...the range being extended as far as needed. Still lower octaves, if needed, are called −1., −2., ...

[4] F. E. ANDREWS, *New Numbers*, New York, Harcourt, Brace, and Co., 1935; G. H. HARDY AND E. M. WRIGHT, *Theory of Numbers*, Oxford Univ. Press, 1945, p. 110; J. V. USPENSKY AND M. A. HEASLET, *Theory of Numbers*, New York, McGraw-Hill Book Co., 1939, p. 13.

The complete specification of any pitch is thus given by two numerals: the number before the dot specifies the octave, the number after the dot specifies the position of the note within the octave. The advantage of this method over the customary designation by letters
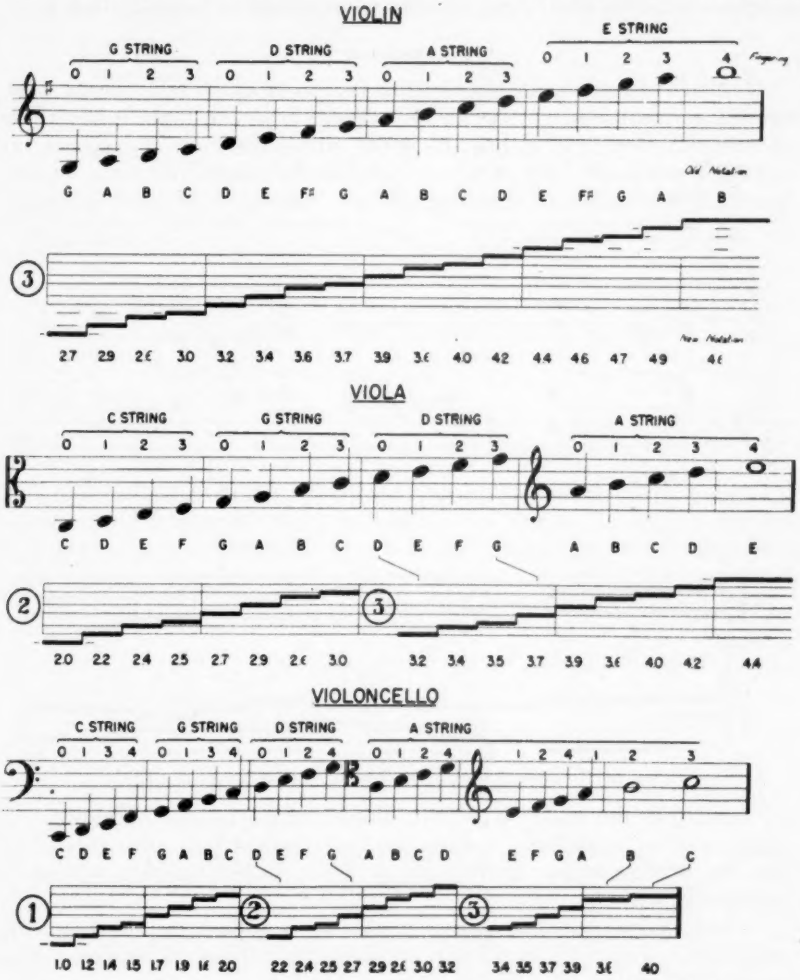
FIG. 6. Fingering for the violin, viola, and violoncello, with corresponding old and new notations.

of the alphabet or by solfège notation is the same advantage that arabic numerals have over Roman numerals. The interval between any two notes specified in the new notation is obtained by merely subtracting the two numbers.

We are dealing here with the *macrostructure* of the octave, which requires only one number to the right of the "decimal point." If at any time, however, we wish to distinguish between the tempered scale and the Ptolemaic or the Pythagorean scale, we need only write more numbers after the dot to get the exact *microstructure* specification.[5]

4. EXAMPLES

The new notation, as described in the previous section, seems very strange and unfamiliar. It can be learned, however, more easily than the old notation, and it has the great advantage that it requires no mental gymnastics but presents visually the exact relations among notes. The number of semitones in any interval is grasped instantly
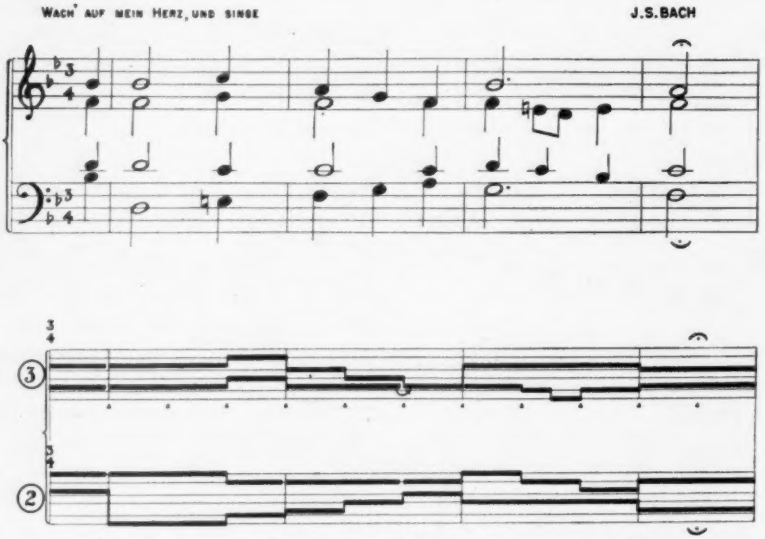
FIG. 7. Example of vocal score using staves for octaves 2 and 3.

by looking at the staff. The only disadvantage, besides unfamiliarity, appears to be a tendency toward too many ledger lines; but this trend can be overcome by introducing a new circled number whenever necessary.

That the proposed notation is feasible is shown by the following examples. Figure 5 shows the approximate ranges of soprano, alto, tenor and bass voices. Using octaves 2 and 3, we find that the voices fit onto the staves about as well as in the old system.

Figure 6 indicates how music for instruments of the violin family would be written in the new system. The customary alto clef for the viola is eliminated without inconvenience, as is the tenor clef for the

[5] PARRY MOON, "A New Specification of Musical Pitch," to be published.

'cello. Note also that the ambiguity in use of second and third fingers, in first-position fingering of the 'cello, disappears in the new notation. All open strings of Fig. 6 correspond to lines of the staff, which helps the beginner in learning the fingering. The customary form on notes may be employed in the new notation (Figs. 3, 4, 5) or a graph may be used (Figs. 1 and 6).

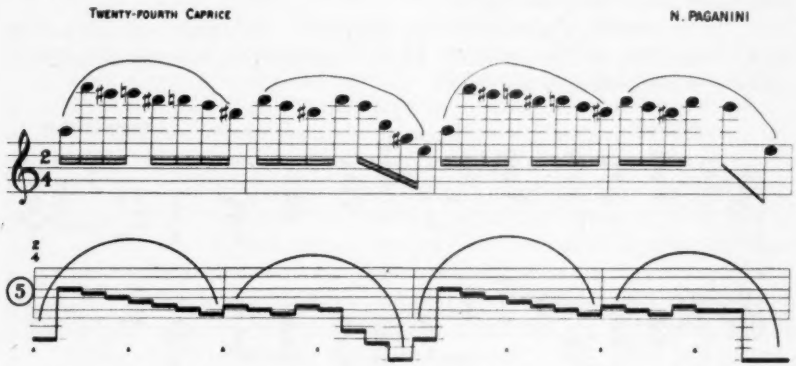

FIG. 8. Violin passage employing staff for octave No. 5.

A vocal phase is written in old and new notations in Fig. 7. The proposed arrangement looks unfamiliar but simple. Figure 8 presents a passage from Paganini's Twenty-fourth *Caprice* for solo violin. The new notation is somewhat more readable than the old. An extract from

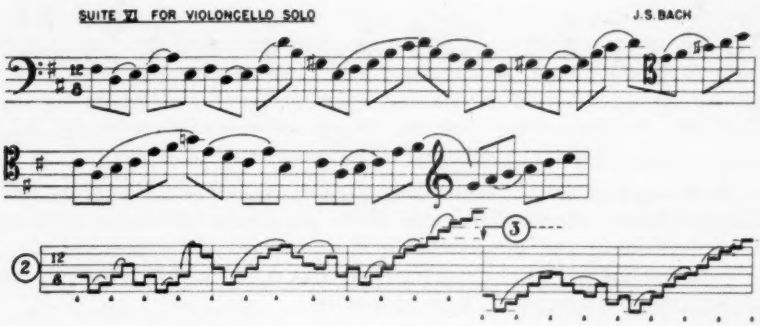

FIG. 9. Example of 'cello music covering a wide range and originally using three clefs.

a 'cello suite by Bach is shown in Fig. 9. The final example, Fig. 10, shows the cleaner score obtained by elimination of accidentals.

5. ADVANTAGES

Advantage of the proposed system of musical notation may be summarized as follows:

a. It simplifies the appearance of the score by eliminating every sharp, flat, or other accidental.

b. It eliminates key signatures and the memory work they entail.

c. It eliminates bass, treble, alto, and tenor clefs with their illogical relationships.

d. It presents a true visual picture from which the intervals between notes can be grasped instantly.

e. It represents a note (say F♯) always by the same position on the staff, regardless of the octave. Thus transposition by any number of octaves is immediately apparent.
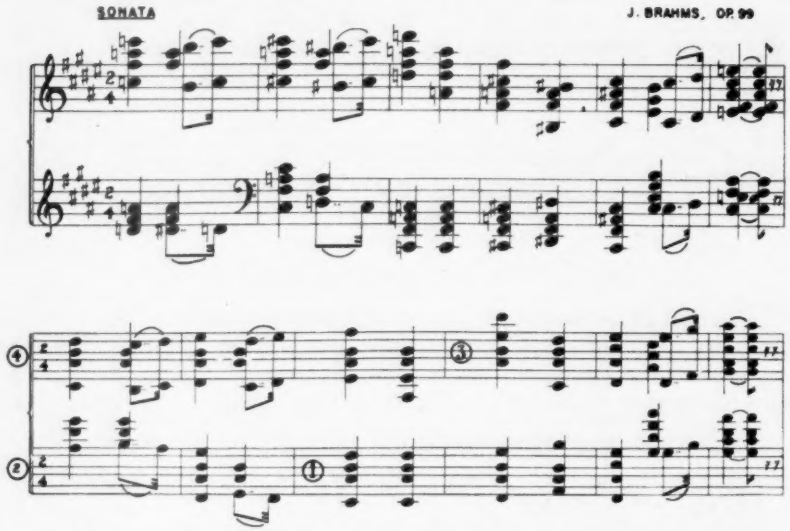
FIG. 10. Piano example, indicating the more legible score obtained by the elimination of accidentals.

f. It associates a definite graphical pattern with each melody. Change of key merely shifts the whole pattern up or down, so transposition is direct and simple.

g. It includes a pitch[3] specification based on arabic numerals and having the advantages of these numerals.

6. SUMMARY

The paper is not based on a fantastic hope that the printed music of two centuries will be suddenly scrapped, to be rewritten in the new notation. Rather, the proposed method is advanced as an aid in *thinking*. In many branches of human activity, man has found that a good notation is half the battle. Such a notation has an almost magic effect in broadening mental grasp and in expediting cerebration.

Perhaps the outstanding example is the alphabet of phonetic type, as contrasted with the non-phonetic symbols of Chinese. Other instances are the graphical representation of functional relationships, which plays such an important role in science, and the index notation (including the Einstein summation convention) of tensor analysis. Still another example is the arabic numeral, as contrasted with the Roman.

The use of the present musical notation is analogous to calculation with Roman numerals. Whether a given pair of notes on the staff makes, for instance, a perfect fifth, an augmented fifth, or a diminished fifth is not obvious in the old notation but requires a mental calculation of a feat of memory. In the new notation, on the other hand, the number of semitones in any interval is obvious at a glance. Moreover, the proposed system presents the same graphical pattern for every major scale, a change of key merely shifting the entire pattern up or down. All minor scales follow another definite pattern. Thus any portion of a scale, encountered in a musical composition written in the new notation, is instantly recognized for what it is, irrespective of the key. Similarly, transposition of a composition means, in the proposed notation, a simple vertical translation of the whole graphical pattern; while in the old system, much routine thought was necessary and errors were easily made.

For these reasons, composers and arrangers of music may find it advantageous to learn the new notation, simply for its mental help. They can easily learn to do their thinking in the modern system; and after their creative work is done, the rewriting of their scores in the traditional notation is mere routine. Also, it would be an interesting experiment to see how much faster students of musical theory and composition would progress if taught to think in the new system. The traditional nomenclature would be learned also, but cerebration would be done in the new system, with resulting improvement in ease and precision.

The musical notation described in this paper is one of many possible modifications of the frequency-time graph.[6] It has a slight resemblance to a system devised by W. H. Thelwall. There is also some similarity to the notation used by Joseph Schillinger.[7] Whatever nomenclature

[6] After writing the above paper, I stumbled upon the "System Godjevatz" (*The New Musical Notation*, V. GODJEVATZ, New York, 1949) which is strikingly similar to the one described here. A 6-line staff is employed (though with different spacing from what I use) and duodecimal numbering is introduced. These strong similarities in two independently devised systems support the idea that any musical notation based on the scientific methods of the 20th century will be essentially the same. See also E. V. HUNTINGTON, "A Simplified Musical Notation," *Sci. Monthly*, Vol. 11, 1920, p. 276; R. W. YOUNG, "Terminology for Logarithmic Frequency Units," *J. Acous. Soc. Am.*, Vol. 11, 1939, p. 134; P. EDWARDS, "A Suggestion for Simplified Musical Notation," *J. Acous. Soc. Am.*, Vol. 11, 1940, p. 323.

[7] J. SCHILLINGER, *The Schillinger System of Musical Composition*, New York, Carl Fischer, 1946.

is finally adopted by the musical world, such nomenclature is almost certain to be a form of log frequency-*vs*-time graph, satisfying the 1:1 relation between log frequency and vertical position and in agreement with the other requirements of Section 2.

In conclusion, I wish to thank Floyd A. Firestone, Klaus Liepmann, Robert W. Young, and Alfred Zighera, who read and criticised the manuscript. I am grateful also to those who wrote the following comments.

DISCUSSION OF "A PROPOSED MUSICAL NOTATION" *

By EUGENE ORMANDY,[1] *Conductor*

In his preface Dr. Moon suggests a new system of musical notation which eliminates the traditional clefs, key signatures and accidentals. A six-line staff is employed, with each semitone on a separate line, space or divided space. May I comment on these two propositions?

First, the traditional clefs were evolved as a part of our musical notation system because of the variation in frequency range of the four human voices, soprano, alto, tenor and bass. The shifting of clefs enables the performer to read the rising and falling musical line without having to resort to the use of excessive ledger or "added lines and spaces." This obviously makes for greater facility in reading music, since there are fewer obstacles in connection with the registration of the visual image.

I believe that a majority of experimental psychologists are of the opinion that the average human being registers no more than five visual units in a single frame. Therefore, I am skeptical of Dr. Moon's plan to introduce a six-line staff. Furthermore, his six-line staff involves the registration of two semitones in two divisions of a space. (See example, Fig. 3.) The slightest irregularity on the part of a copyist or an engraver would, as a consequence, horribly distort harmonic combinations.

May I sum this up by saying that the six-line staff with these added complexities, presents a major problem for rapid reading as compared with the five-line staff with accidentals now in common use.

Dr. Moon's proposition to eliminate key signatures indicates that he subscribes to the a-modal or "equality of the twelve-tone system," which has been proposed by Arnold Schönberg and his whole school of

* Since the system of musical notation proposed in Parry Moon's paper represents a radical change from the present system, the editors of the JOURNAL felt that opportunity to discuss the proposals should be given to several musicians representing the points of view of conductors, music publishers, soloists, teachers, composers, and theorists. Invitations were issued to one musician from each of the above-mentioned groups and the editors are pleased to publish their comments.

[1] Music Director, The Philadelphia Orchestra Association, Philadelphia, Pa.

musical-composition theory. Undoubtedly, the Schönberg school has created an interesting, new and colorful musical literature which can be considered an important contribution to the over-all evolution of the tonal art. No psychologist or physicist of great standing, however, will contend that this new musical philosophy can supersede that which has been effective and in force throughout the past several thousand years.

This traditional musical theory which evolved in ancient China and which was so beautifully documented by Pythagorus, Aristotle, and other mathematical philosophers, is based on a system of tonal relationships which are easily demonstrated. The ancient Greeks' demonstration of this was by means of tones of variable frequencies that were harmonious in combination and were produced by vibrating bodies that were exactly fractional in dimensions. With the advent of electrically synthesized sound, and equipment for accurate measurement of sound frequencies, the fundamental principles of the ancient Chinese, ancient Greek, Roman and Medieval theorists, and the whole of our modern traditional musical system, has been completely verified.

If a great part of the important music of the past and the present is founded on a theory and philosophy which recognizes tonal-systems and if these tonal-systems are clearly presented to the eye through the use of key signatures, I cannot understand why Dr. Moon should wish to eliminate key signatures.

May I sum up all that I have said briefly?

Our current musical notation system is at best 80 per cent efficient. It must present to the eye symbols which indicate the frequency, the duration and the intensity of all tones used in sequence or in combination. Extraneous notation symbols are frequently interpolated in an attempt to overcome the 20 per cent deficiency of our current system and these often impede exact interpretation of the composer's requirements. I do not find that Dr. Moon's notation system would eliminate the use of extraneous indications.

Also, I find Dr. Moon's rhythmic indications—that is, system of indicating length of note—very simple when dealing with uncomplicated rhythm, but I am afraid it is inadequate if one considered it as a means of indicating complex rhythmic patterns.

The use of the various clefs may require a little additional training. I don't believe, however, that Dr. Moon's system of notation offers any simplification. I do not find that Dr. Moon's notation is readily grasped by the eye and I do not feel that he has made any suggestion for an indication of the intensity or degree of loudness for the tones without the use of extra symbols.

I find in the paper much that is new and exciting, but I believe there would be greater losses than gains in any attempt to adopt such a new system.

By WALTER HINRICHSEN,[2] *Music Publisher*

It is rather difficult to discuss Dr. Moon's proposed musical notation exclusively from the point of view of a publisher of music. A publisher, it is true, must view the music he issues from certain special points of view, but he is primarily concerned with the music itself. There are a few technical objections to Dr. Moon's system which are present even as the music is being engraved, but it would only be the customers' reaction to the product that could give a definitive answer and would determine whether a publisher would or would not be willing to follow Dr. Moon's suggestion. We are thinking of those notes which Dr. Moon has chosen to indicate in such a way that they seem to be snuggling against a line. The problem becomes immediately apparent as soon as the system is used for depicting an actual musical composition instead of a simple graph; for example, in the second half of Fig. 10, a brief extract from Brahms' Sonata for Violoncello and Piano. Certainly in a large chart, such as that given in Fig. 2, and perhaps in a part written for a solo instrument, these slight displacements might be sufficient to be perceived, but we very much doubt that many musicians would find that notation of this sort is as easy to grasp as the more complicated standard system in general use today. Conceivably, if all music were printed on staves with widely spaced lines, the time might come when performers could accustom themselves to such small differences, but even so, Dr. Moon's new notation would be setting them a further problem to overcome. Likewise, he would be making things more difficult and costly for the publisher, who would invariably have to have his publications engraved on widely spaced staves. Until he could be quite certain that all musicians were equipped with 20–20 vision, he would hardly dare to issue another miniature score.

When Dr. Moon quotes from Dr. Scholes in criticizing the present notation, we should remember that Dr. Scholes gives as examples of compositions for which the present notation is inadequate "a later work of Scriabin or Schönberg." These men and some few others have gone on to writing music that is not based on the conventional diatonic system, and Schönberg has formalized his use of all twelve notes of the chromatic scale into a specific "twelve-tone system." Much contemporary music and practically all earlier music, even when it eventually uses all twelve notes before the composition's conclusion, does not use the tones in close succession.

Most music is written on a seven-note scale. In medieval times, this seven-note configuration was felt to be so inevitable that composers rarely bothered to indicate the accidentals, with the result that now musicologists must struggle with the thorny problems of *musica ficta* and try to decide which of the unmodified notes should be sharped and which flatted. The accidentals were introduced only very gradually

[2] President, C. F. Peters Corporation, New York, N. Y.

and primarily for the purposes of transposition of the entire work; it was only much later that composers came to use them for modulating from one key to another in the course of a single composition. The time came later when the careful balancing of the keys produced the basic structure of the sonata form, and eventually when all of the logical possibilities of such structures had been elaborated, it was inevitable that composers would try to increase the richness of their compositions by modulating from one key to another more rapidly. Since they were still thinking in terms of the seven-note diatonic scale, however, these modulations must still be heard as changes from one key to another, not simply as random introduction of accidentals. In other words, the accidentals have a very specific function to perform in indicating the structure of the composition, and hence even if a g-sharp and an a-flat sound the same when struck on a piano, they are quite separate and distinct notes in the key-structure of a musical work. To attempt to reproduce such a diatonic composition in a notation without accidentals to show what these key relations were would simply rob the performer and student of the score of his most helpful and explicit clues for understanding the structure. Thus we can see no useful purpose that would be served by trying to apply Dr. Moon's accidental-less notation to any type of music where the accidentals have a definite function to perform. A triad may be modified in various ways, but it still remains a triad. In the accepted system, it continues to look like a triad throughout all of these modifications, since in its root positions it will appear on three successive lines or spaces of the staff. In Dr. Moon's system, an augmented, diminished, major, or minor triad would all look quite different.

The situation is, of course, altered when we come to the twelve-tone composers. Here some such system as Dr. Moon's begins to seem more logical, since the accidentals have ceased to perform any meaningful function in the structure of the composition, and the twelve notes all have more or less the same weight. For a publisher, however, this distinction does not as yet have too much meaning. Issuing twelve-tone compositions is still very much a luxury for any publisher, and few firms have any large number of such works in their catalogs. As long as the seven-tone diatonic music is in general demand and dominates the field as completely as it does today, it is only practical to realize that this music will be published in a style of notation suitable to it. Conceivably, some minor modifications may be introduced into the conventional system of notation, but for the most part it seems almost certain that diatonic music will continue to be published in a system substantially similar to that in which it was written. And if a publisher must choose between two systems of notation—one known to all musicians and the other still known to few—it is not difficult to see which he will choose, even for the twelve-tone compositions.

By ELSA HILGER EZERMAN,[3] *Soloist*

Examining the new musical notation as suggested by Parry Moon with a soloist's eye restricts one's view to just one phase of the process of bringing music from the composer's inspiration to performance of the written music, namely, translating the notations on paper into audible music, via one instrument or another. With this in mind, and ignoring other angles of the question, which will be taken into consideration by the musicians in other fields, I will try to give an opinion of this new notation from the soloist's point of view.

Primarily, the soloist regards printed music or manuscript music solely with regard to the ease with which it can be read. Thus, music which has been reduced in size by reprinting with the offset method, imperfect or light inking of the press, staves too near each other, crowded notes and accidentals and oddly shaped notes and accidentals are a source of irritation and fatigue. Here lies, in my opinion, the first and most definite fault of the new notation as reproduced in Figs. 3–10; the old notation is definitely more legible at music stand distance than the new. This could, of course, be readily corrected by a wider staff, with proportionately larger notes. In the larger staff, the two double spaces might be made even wider to avoid manuscript ambiguity.

Learning to read the new notation should be a problem of minor importance. Cellists and bassoonists must learn the tenor clef, and violinists turned violists must learn that clef, and no musician has ever made serious complaint. Learning to follow readily the step-up, step-down, continuous line notation instead of the whole note, half note, quarter note notation presents greater difficulty. True, the accidentals are not there, and to the casual eye the chromatic scale is remarkably easy to follow, yet the old eliptical notes are more easily seen at music stand distance. There are also difficulties possible in an instance such as a double dotted quarter note and a sixteenth, or a repetition of the same note in various values. Altogether, I found the piano example (Fig. 10) considerably easier to read than the cello example (Fig. 9).

Since the soloist is often asked to read manuscript music, and since many composers are poor hands at draftsmanship, I shudder to think how a poor draftsman would mangle the lineal notation.

I am a bit dubious about the value of departing from the alphabetical designation of pitch to the duodecimal system. Calling a B natural "one point epsilon" or "three point epsilon" does have the advantage of locating the pitch of that particular note, but it certainly shakes our old system down to its very foundations, as no other phase of this system does!

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[3] Cello Soloist, The Philadelphia Orchestra, Philadelphia, Pa.

By HELENE DIEDRICHS,[4] *Music Teacher*

On reading Dr. Parry Moon's paper entitled "A Proposed Musical Notation," I feel that there are several reasons against its adoption. I shall confine my attention to the three which seem to me the most important.

Harmonic Relationship. Key relationships are fundamental to the logical significance of the harmony of our epoch. While D-sharp and E-flat sound the same on the piano, they are very significantly different in their harmonic meaning and this meaning reflects itself in the beauty and content of the composition. The stringed instrumentalist and the singer will actually differentiate between these two notes in the matter of pitch, and even the pianists, though powerless to make this contrast, will be conscious of the difference and will simulate the intent of the composer by adjustments of intensity and rhythm. Thus, with the new notation, the significance of harmony would be lost.

Composition. The author suggests that composers would benefit in speed and accuracy by thinking in the new notation. I think this conclusion is to be questioned.

If there is one place in music where harmonic relationships and the niceties of their expression are important, it is in composition. To be specific, I will state but one point which would be lost in the new notation, that is the enharmonic change referred to above. There are innumerable instances in great compositions where this effect has been used, creating great beauty in color and interest. Harmonic relationships are the building material of composition and it would seem that anything which, for the sake of simplicity and speed, tended to weaken the content of harmonic relationship, would rob the composer of the essential material which he uses in his craft.

Sightreading. The author's claim that sightreading would be facilitated is debatable. Unquestionably the new notation would be easier visually, but this does not mean that it would make better sightreaders. To do anything well requires the wish to do it and effort expended on it. Anyone can learn to sightread with effort. I venture to say that the bad sightreaders do not put that effort into it. They are simply lazy over it. With the new notation the good sightreaders would put forth less effort—the result being equally good. The "lazy" sightreaders would put forth less effort and the results would be equally bad. Many children read well in the old notation. Surely it cannot be too difficult!

[4] Presser Studios, Philadelphia, Pa.

By PAUL HINDEMITH,[5] *Composer*

In my opinion, notations cannot be introduced by just inventing another graph and asking the musicians' opinion. The only way to find out whether a notation system is of any value would be to provide about twenty sheets of old and new compositions of all kinds of styles and for different instruments, let musicians actually play from them, and later, after they were given ample time to get acquainted with the new system, ask them what their reactions are.

By J. L. BAWDEN,[6] *Theorist*

Such schemes have been attempted before and are so remote from any realization that, to the practical musician, they remain little more than interesting games. The enormous problem of printing alone, with the industrial and educational problems involved, is a barrier.

The author indicates that at present this system should be considered rather as a means of clarifying a composer's thought than an attempt at an actual reform, but any competent composer knows his language and his notation very well indeed and hardly feels himself limited in that direction.

Author's closure, by PARRY MOON

It is not surprising that musicians view with suspicion any proposal to modify something so hallowed by tradition as is musical notation. And such feeling is even more understandable when one considers the fact that present notation is universally and actually workable. In fact, I am sure that only the politeness of the commentators kept the foregoing printed criticisms at their uniformly suave level.

The professional musician does not realize the clumsiness of our antiquated notation: years of concentrated effort have made him complete master of it. Nevertheless, the system forces him to do a great deal of mental work which is completely unproductive and which would be eliminated by better nomenclature. A direct relation between sound and symbol is needed, so that the reader can grasp the melodic and harmonic patterns instantly without floundering in a mass of archaic symbolism.

Any good plan should give 1:1 correspondence between pitch and vertical position on the staff. Such a correspondence is obtained with the familiar 5-line staff when music is limited to the 7 notes of the C-major scale. If we confine ourselves to 16th-century modal music, the 5-line staff is ideal. Or if we restrict ourselves to the modes of a pentatonic scale, a 3-line staff is adequate, as shown by Yasser.[7] But

[5] Music School, Yale University, New Haven, Conn.

[6] Chairman of the Theory Department, Philadelphia Musical Academy, Philadelphia, Pa.

[7] J. YASSER, "Evolving Tonality," New York, Am. Lib. of Musicology, 1932.

when we insist on the availability of 12 notes per octave, we are forcing the 5-line staff to do work for which it was not designed and for which it is not fitted. The difficulty reaches its most aggravated form in atonal music, but the trouble is present in all Western music from Bach to Wagner.

Specific criticisms of the proposed notation may be divided into two groups—those concerned with details of notation, and those dealing with harmonic structure and enharmonic change. Size of staff, number of lines, spacing, size and form of notes are details that influence readability; and further research is needed on all of them. If the traditional form of note is retained in the new system (Fig. 10), and the size of note is unchanged, readability will be at least equal to that for the traditional notation. If heavy horizontal bars are used instead of notes, it seems that good readability should be possible without undue increase in staff size. With regard to manuscript, the old notation is notoriously difficult to write and is responsible for plenty of illegible scores. A composer might find the horizontal bars of Fig. 9 easier to draw than the customary notes; in fact, he might even use a ruling pen and a straightedge, with resulting improvement in legibility.

Of greater importance than these details is the second group of criticisms, which may be summarized in the single question, "Is the musical score merely a frequency-time graph, or is it something more?" In other words, does the musician find something in the score that the less-sensitive scientist is unable to find? Undoubtedly the old notation does give some help in the harmonic analysis of an unfamiliar composition. It seems likely, however, that just as much information could be obtained from the new notation if one were familiar with it. As Huntington[8] says of a somewhat similar proposal:

> It is on the side of analysis that the only serious theoretical objections to the new plan are likely to be raised. For one thing, the guidance to keychanges which accidentals in the present scores now provide would be lacking in the new plan. . . .
>
> In reply to these objections, it may be said that whatever is actually present in the music as heard by the ear is faithfully reproduced in the new notation as seen by the eye. Hence it follows that the new notation omits nothing which is really essential for the analysis of the music as sound. *All that it discourages is an analysis of the symbolism of an obsolete notation.*

[8] E. V. HUNTINGTON, *Sci. Monthly*, Vol. 11, 1920, p. 276.

Dynel Drapes Feature Their Own "Built-in Fire Extinguisher".—Even a blowtorch can't send drapes of dynel up in flames!

Dynel, another new contribution by chemists to better living, is a fiber developed in the laboratories of Union Carbide and Carbon Corporation. Processed in twelve different chemical steps from basic gases, salt and air, it is now being made into drapes beautiful to look at, beautiful to feel—yet so fire-resistive they have been approved by official bodies as safe for use as draperies in hotels, places of "public assembly," and passenger ships.

Dynel is self-extinguishing, won't support combustion. The new fiber will burn slowly at the point of direct contact with an open flame, but its permanent "built-in fire extinguisher"—vinyl chloride, comprising 60 per cent of the fiber—stops the burning when the flame is removed! That's why a blowtorch can be applied to dynel drapes without setting them aflame.

But resistance to fire is only the beginning of the amazing combination of much-wanted advantages inherent in dynel drapery fabrics. They are delightfully soft and pleasant to the touch—so different from the harsh "hand" of many fireproofed materials. They're handsome, long-wearing, wonderfully easy-to-care-for.

In addition, dynel drapes are completely washable. It's safe to put them in a washing machine because they don't shrink. They dry quickly, too. There's no sagging or stretching when they're hung—they drape beautifully. And they wear for years, because dynel is a fiber of great strength and toughness.

And that's not all. Dynel has extraordinary resistance to chemicals and stains. Most acids and alkalis, soaps and detergents will not harm it. Many stains wash out with plain soap or detergent and water. Most others are removed easily with bleaches.

Summer use or storage brings no problems at all. Because dynel is absolutely mothproof and mildewproof, the only storage requirement is space in a closet. Moths won't ever eat dynel. In tests, moths not only would not eat dynel as food, but refused to eat through it to get at food on the other side of the dynel—as they do with other fibers. Instead, they starved to death. That mildew does not harm dynel fabrics is shown by the results of six-months burial tests in damp tropical soil. The dynel was taken out of the ground after that length of time, completely unaffected.

Yet these drapery fabrics with so many "easy-care" features are as attractive-looking as the most luxurious fabrics made from natural fibers. Made by Hafner and Thorp, they are beautifully colored and designed, and their fire-resistive factor makes for safe living all year round. These new drapes have the unique combination of luxury and practical advantages that only dynel, science's newest fiber, provides.

A device to measure the arterial pulse wave has been developed by the Air Force School of Aviation Medicine at Randolph AFB. The mechanism transforms the mechanical movement of the arterial wall into an electrical signal, using a mechano-electronic transducer in the form of a subminiature radio tube, originally designed for phonograph pickups. Measurement of the pulse wave is used in investigation of the cardiovascular response to postural changes during mild hypoxia, may lead to new techniques of resistance to high altitude stress.

RADIATIONS FROM RADIOACTIVE RHODIUM (105) *

BY

C. E. MANDEVILLE [1] AND E. SHAPIRO [1]

ABSTRACT

The characteristic radiations of the 36-hr. rhodium (105) have been investigated with the use of conventional absorption and coincidence methods. The beta rays were found to have a maximum energy of 0.55 Mev., and the gamma rays a quantum energy of ~0.3 Mev. The beta-gamma coincidence rate of Rh^{105} indicated that less than 8 per cent of the beta rays are coupled with the gamma ray.

INTRODUCTION

When ruthenium is irradiated by slow neutrons, two radioactive isotopes of ruthenium are formed, the 42-day Ru^{103} and the 4.5-hr. Ru^{105}. The 42-day activity decays to stable Rh^{103}, but the 4.5-hr. period forms as its daughter element, the 36-hr. Rh^{105} which in turn decays to stable Pd^{105}. The radiations of the 36-hr. Rh^{105} have been previously examined by several groups of investigators (1)[2], with the use of conventional absorption methods. Observations on the characteristic radiations of Rh^{105} were also reported upon briefly by the writers (2), who found a beta ray of energy ~0.6 Mev. and a gamma ray of energy ~0.3 Mev. Approximately the same beta ray energy had been previously reported by all the investigators of reference 1, and the gamma ray had been previously observed by Sullivan, Sleight, and Gladrow (1). Subsequent to all of the above-mentioned investigations, spectrometric and coincidence measurements were carried out on the radiations of Rh^{105} by Duffield and Langer (3), who accurately determined the beta ray energy as 0.570 ± 0.005 Mev., but who did not observe any gamma rays. Following the report by Duffield and Langer (3), the writers obtained a second source of Rh^{105} for further study. The results were essentially the same as those first obtained (2). The discussion which is to follow will concern itself with data resulting from observations on both sources.

PROCEDURE AND RESULTS

The 36-hr. rhodium (105) was grown from its 4.5-hr. ruthenium parent when metallic ruthenium was irradiated by slow neutrons in the Oak Ridge pile. For the first sample of rhodium, the time of irradiation was 24 hr. This time was reduced to 10 hr. when the second

* Assisted by the joint program of the ONR and the AEC.

[1] Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

quantity of material was irradiated almost a year later. The same chemical procedure was employed in the case of both sources. The ruthenium target material was purified before exposure by distillation of RuO_4 from a perchloric-sulfuric acid solution of chemically pure $RuCl_3$. After irradiation in the pile, Ru was dissolved in a mixture of 10 parts conc. HCl, 1 part conc. HNO_3, at 160° C. Rhodium carrier was added to the Ru solution, and RuO_4 was distilled from a perchloric-sulfuric acid solution. Inactive $RuCl_3$ was added to the residue and another RuO_4 distillation effected. The residue in the distillation flask was diluted to 1 *M* in acid and treated while hot with magnesium

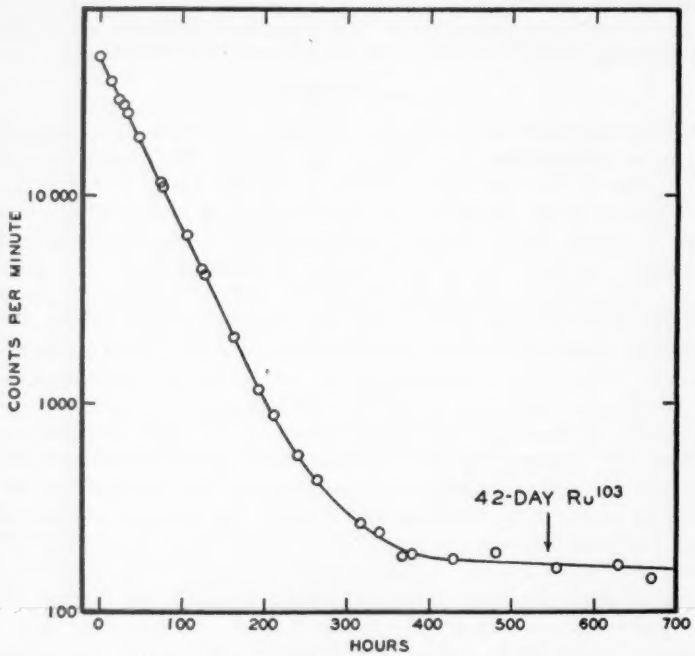

FIG. 1. Half-period of the total activity of Rh^{105}.

powder to precipitate rhodium. After dissolving excess magnesium in HCl, the suspension was filtered, the rhodium washed with HCl, hot water, alcohol, and ether, then dried.

The activity of the 36-hr. rhodium was followed for more than 300 hr. as shown in Fig. 1. The half-period taken from the slope of the curve was calculated to be 36.8 hr. A faint residual activity of long half-period is clearly present, and this is assigned to the presence of a trace of the 42-day Ru^{103}. This decay curve was considered as good evidence for high purity of the source. Using a thin source of the

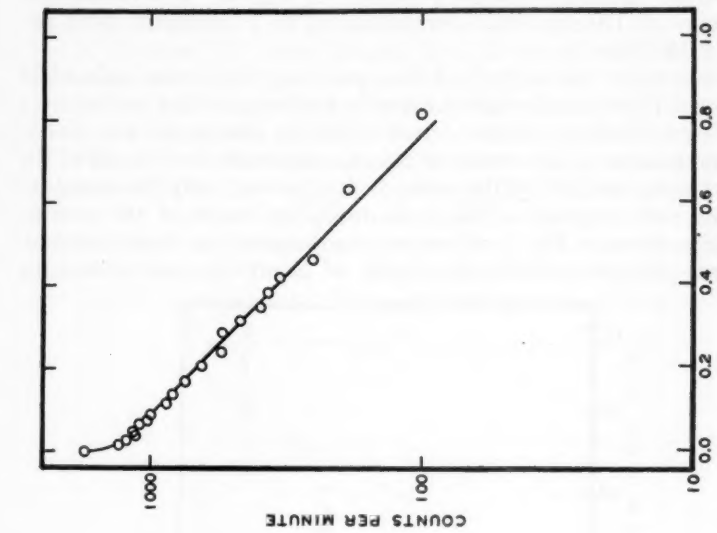

FIG. 3. Absorption in lead of the quantum radiations emitted in the disintegration of Rh^{105}.

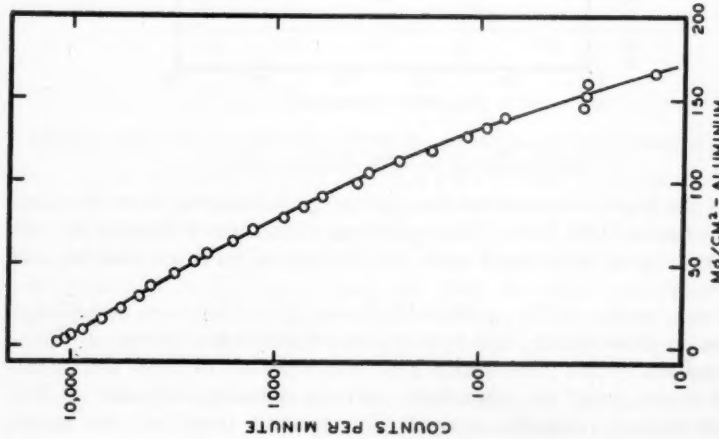

FIG. 2. Absorption in aluminum of the beta rays of the 36-hr. Rh^{105}.

purified Rh^{105}, the beta ray activity was absorbed in aluminum in a thin window "bubble" counter as shown in Fig. 2. The absorption limit occurs at 170 mg./cm.^{2}, corresponding to a maximum beta ray energy of 0.55 Mev.[4].

To investigate the nature of the quantum radiations emitted in the decay of Rh^{105}, an absorption curve in lead was carried out before a single Geiger-Mueller counter. Just sufficient aluminum was placed before the counter at the outset of the measurements to stop all of the beta rays being emitted by the source. In this way, only the quantum radiations were counted. This lead-absorption curve of the gamma radiation is shown in Fig. 3, where two components are clearly present. The softer component is in the region of X-rays or bremsstrahlung

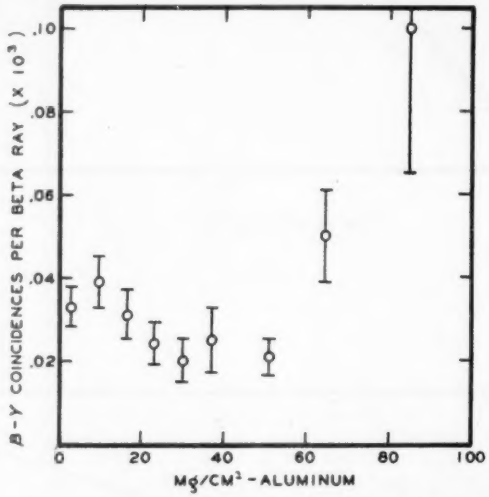

FIG. 4. The beta-gamma coincidence rate of Rh^{105} as a function of the surface density of aluminum placed before the beta ray counter.

whereas the harder component has an energy calculated from the slope of the curve as 0.36 Mev. The quantum radiations indicated by this curve are in good agreement with the findings of Sullivan, Sleight, and Gladrow (1).

When a source of the purified Rh^{105} was placed between two Geiger counters in coincidence, the beta-gamma coincidence curve of Fig. 4 was obtained. The coincidence rate was very small, and the points beyond 60 mg./cm.^{2} are essentially without meaning, because of their great statistical probable errors. The general trend of the points below 60 mg./cm.^{2} is downward, indicating that the gamma ray of Rh^{105} is coupled with an inner beta ray group. The gamma ray counter of the beta-gamma coincidence counting arrangement was calibrated

by the beta-gamma coincidence rate of Sc^{46}. From the calibration, it was calculated that the beta-gamma coincidence rate of Rh^{105} at zero absorber thickness ($\sim 0.04 \times 10^{-3}$ coincidence per beta ray) is what would be expected, were gamma rays of energy ~ 0.3 Mev. coupled with not more than 8 per cent of the beta rays.

The data of the first four figures of this paper were taken with the use of the first source of Rh^{105} obtained from Oak Ridge.

Since a question had arisen whether quantum radiations were present at all in the decay of rhodium (105) (3), the second source of radioactive material was procured from Oak Ridge for a more careful consideration of the gamma ray activity. The target material was irradiated for only 10 hr. in the pile, and after chemical purification, was placed between two blocks of aluminum, each having a surface

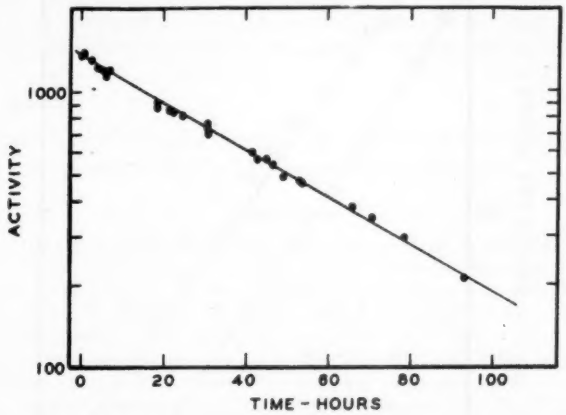

FIG. 5. Half-period of the gamma ray activity of the second source of Rh^{105}.

density of 1.7 g./cm.^{2}. This aluminum thickness was, of course, far more than sufficient to stop the beta rays of Rh^{105}. Adjacent to either aluminum block was placed a Geiger-Mueller tube, having glass walls of thickness 0.1 cm. and copper cathodes of wall thickness 0.013 cm. In one counter, the half-period of the quantum radiations being emitted by the source of Rh^{105} was measured; with the other, absorption curves in lead of the gamma rays were obtained. The decay curve of the gamma ray activity of Rh^{105} was followed for three half-periods and is shown in Fig. 5. The half-period, taken from the slope of the curve is 35 ± 1 hr. Two lead absorption curves for the gamma rays of Rh^{105} are shown in Fig. 6. The first of these curves was taken at the beginning of the decay curve of Fig. 5, and the second curve was obtained forty hours later. The quantum energy taken from the slope of the curves is 0.3 Mev. These curves differ from that of Fig. 3 in that the

softer component has now disappeared and the slope of the curve for the hard component is such as to suggest a quantum energy of 0.30 Mev. rather than 0.36 Mev. Absence of the softer component is explained by the fact that the thick block of aluminum was used before the gamma ray counter in the second measurement. The change in slope to give the differing quantum energies is explained by the fact that the geometries of the two sets of lead absorption measurements were vastly different. It is thought that the same gamma ray is certainly involved in both instances.

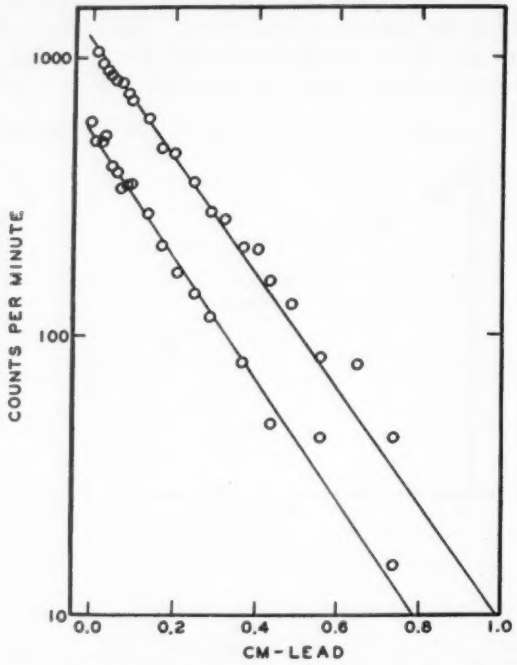

FIG. 6. Absorption in lead of the gamma rays emitted in the disintegration of the second source of Rh^{105}.

The question arose whether the presence of quantum radiations might be accounted for by bremsstrahlung effects. This seemed to be an unlikely explanation for the presence of the gamma rays, because the mean energy of the beta rays from Rh^{105} is only 0.2 Mev.[3]. However, to show positively that the results are not in any way related to the presence of bremsstrahlung, comparative measurements were carried out, using the beta spectrum of RaE. The source of Rh^{105}, the gamma ray activity of which had been followed for three half-periods, was placed before a thin window "bubble" counter. The beta ray counting

rate was observed, and after 0.1 cm. of lead had been placed before the counter, the gamma ray activity was likewise noted. The source of Rh^{105} was removed; a source of Ra (D + E + F) was positioned to give the same beta ray counting rate as was previously observed for Rh^{105}, and the same sheet of lead was placed over the counter to observe the residual counting rate. The data are given in Table I where it is

TABLE I.—*Gross Counting Rates (per minute).*

Background	Ra (D + E + F)	Rh^{105}
37.5 ± 3	39 ± 4.5	116 ± 4

clear that although the counting rate from Ra (D + E + F) did not exceed the background count, that of Rh^{105} was three times greater. Were the quantum radiations which were detected in the counter originating from bremsstrahlung production in the lead sheet, the counting rate from Ra (D + E + F) should have been the larger, because the beta rays of RaE have a maximum energy of 1.17 Mev.

Acknowledgment

The writers wish to acknowledge the continued interest of Dr. W. F. G. Swann, Director of the Bartol Research Foundation.

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(2) C. E. MANDEVILLE AND E. SHAPIRO, *Phys. Rev.*, Vol. 80, p. 125 (1950).

(3) R. B. DUFFIELD AND L. M. LANGER, *Phys. Rev.*, Vol. 81, p. 203 (1951).

(4) L. E. GLENDENIN, *Nucleonics*, Vol. 2, No. 1, p. 12 (1948).

High-Accuracy Drive for Spinning Synthetic Yarn.—The General Electric Company has announced development of a new drive for spinning machines that is designed to provide greater uniformity of denier and dye-ability of synthetic yarns than ever before obtainable.

This all a-c. drive insures uniformity through the most precise speed control (one-tenth of one per cent over a 7:1 speed range) ever obtained for spinning machines motors, according to G.E. engineers.

The system utilizes an electronically-regulated a-c. adjustable-speed motor, which drives a variable frequency alternator through a two-speed, herringbone gear box. The alternator output is delivered direct to small, synchronous motors on the spinning machine. These motors, in turn, provide direct drive to the machine positions, and eliminate troublesome and costly gearing, tapes, and line shafting.

Requiring only about two-thirds of the floor space needed for a comparable d-c. drive, the new system provides greater operational efficiency with fewer electric machines. Lower maintenance expenses and savings in power consumption are other major advantages.

New Instrument Monitors Area Gamma Radiations.—A new instrument that detects and records dangerous gamma radiations in an area and sounds an alarm when average tolerance limits are exceeded has been announced by the Meter and Instrument Department of the General Electric Company.

Called an "area health monitor," the device provides instantaneous indication of radiation, total radiation received in any present period, and a thirty-day integrated record of the radiation present in the immediate vicinity of the detector in fifteen-minute intervals. It also contains a means of telemetering the rate of radiation to remotely located indicating stations.

In operation, the area health monitor measures and records the gamma—or X-ray's ionizing potential—the important factor in determining the effect that radiation will have on human tissue.

According to G.E. engineers, it is designed as an addition to the present safety and civilian-defense equipment installed in laboratories, atomic-energy plants, hospitals, water works, and other areas requiring records of X-ray or gamma radiations. They pointed out, however, that the new monitor is not meant to replace personnel film badges or chambers carried by workers who frequent places where radioactivity is present, but rather to monitor whole areas.

The standard equipment consists of an air wall ionization chamber, a d-c. amplifier, and a 6-ft. instrument panel that incorporates a torque-balance converter, a watthour-meter mechanism, a rate indicator, a cyclometer counter, and a recording device. Since the area health monitor uses an air equivalent ionization chamber as its primary source, it is not dependent upon the energy of the source, the engineers said.

Its range is $\frac{1}{2}$ to 5 times tolerance (tolerance is 6.25 milliroentgens per hour), with an over-all plus or minus accuracy of 10 per cent. Operation is on a power supply of 60 cycles, 115 volts.

TRANSIENT VIBRATION OF LINEAR MULTI-DEGREE-OF-FREEDOM SYSTEMS BY THE PHASE-PLANE METHOD

BY

R. S. AYRE [1]

ABSTRACT

This paper shows the application of phase-plane graphical methods to transient forced vibrations of undamped, linear systems having more than one degree of freedom. Lumped parameter as well as distributed parameter aystems are included. An introductory application to a single-degree-of-freedom system is followed by examples relating (1) to the two-degree-of-freedom two-mass system, (2) to the two-degree-of-freedom single-mass system with inertia coupling, and (3) to a simply supported uniform beam. The essential feature is the independent application of the phase-plane method to each *normal* coordinate of a system.

INTRODUCTION

Phase-plane methods are well known in the investigation of the steady oscillations of non-linear vibrating systems having one degree of freedom (**1**, **2**, **3**).[2] They have also been applied to another class of problems in which a known transient disturbance acts on a system having either linear or non-linear characteristics and for which a step-by-step solution is indicated (**4**–**10**). The most comprehensive papers of the latter class apparently are those of J. Lamoen, which were published in 1932–35 (**4**, **5**).

It is the purpose of this paper to show the application of phase-plane methods to the transient vibration of undamped *linear* systems having *more than one* degree of freedom. The extension is such an obvious one that it can scarcely be new; however, the author is not aware that it has been published. It will first be necessary to examine the single-degree-of-freedom case.

SINGLE-DEGREE-OF-FREEDOM SYSTEM

The system of Fig. 1 is acted upon either by a ground displacement $y_g = Y(t)$, or by a force $F = f(t)$, where $Y(t)$ and $f(t)$ are known functions of time t, and where the differential equation of motion[3] is

$$m\ddot{y} + ky = k \cdot Y(t), \quad \text{or} \quad f(t). \tag{1}$$

It is assumed that the forcing function may be replaced by a stepped approximation in which it is generally desirable to make the area of each

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

[3] Since it is obvious that the forcing functions $k \cdot Y(t)$ and $f(t)$ are equivalent to each other, the discussion will hereafter be in terms of $k \cdot Y(t)$.

step equal to the area under the portion of the curve replaced by the step (equal impulse). Figure 2 shows the construction of the $(\dot{y}/p, y)$ phase-plane, where the circular natural frequency is $p = \sqrt{k/m}$, and where the starting conditions are $y = 0$ and $\dot{y} = 0$ at $t = 0$.[4]

The procedure shown in Fig. 2(*a*) and (*b*) is simply a graphical integration of Eq. 1, consisting (1) in plotting $Y(t)$ by a series of steps having the heights $Y_1, Y_2, Y_3, \cdots$ and the time durations $t_1, (t_2 - t_1), (t_3 - t_2), \cdots$, (2) in constructing the phase-trajectory, which for problems of this type consists of connected circular arcs (constant energy curves, also, integral curves) generated in succession by a vector rotating with constant angular velocity p, through the angles $pt_1, p(t_2 - t_1), p(t_3 - t_2), \cdots$, the angles being centered about the instantaneous posi-

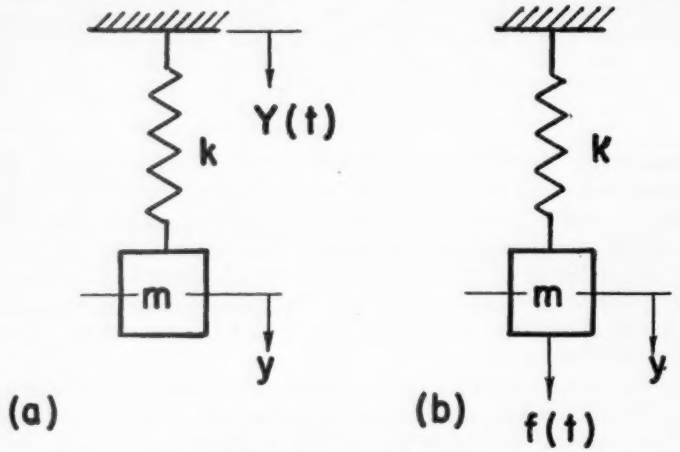

FIG. 1. Single-degree-of-freedom system.

(*a*) Acted upon by a ground displacement $Y(t)$
(*b*) Acted upon by a force $f(t)$

tions of equilibrium, $Y_1, Y_2, Y_3, \cdots$, and finally (3) in constructing the displacement-time curve by horizontal projection from the phase-trajectory. The last step can be omitted if the maximum displacement alone is wanted. When the forcing function is a ground motion the *relative* displacement or spring distortion, $y_r = y - Y(t)$, can be determined directly from Fig. 2(*b*).

The accuracy of the solution depends upon the number and distribution of the steps (9). A little experience in solving simple problems for which there is a known solution will assist greatly in making a reasonable choice of steps for more complicated functions. The stepwise nature of the solution results in slope discontinuities in the

[4] Any other starting conditions, $y = y_0$ and $\dot{y} = \dot{y}_0$, could have been used by plotting in the phase-plane the initial coordinates $\dot{y}_0/p, y_0$.

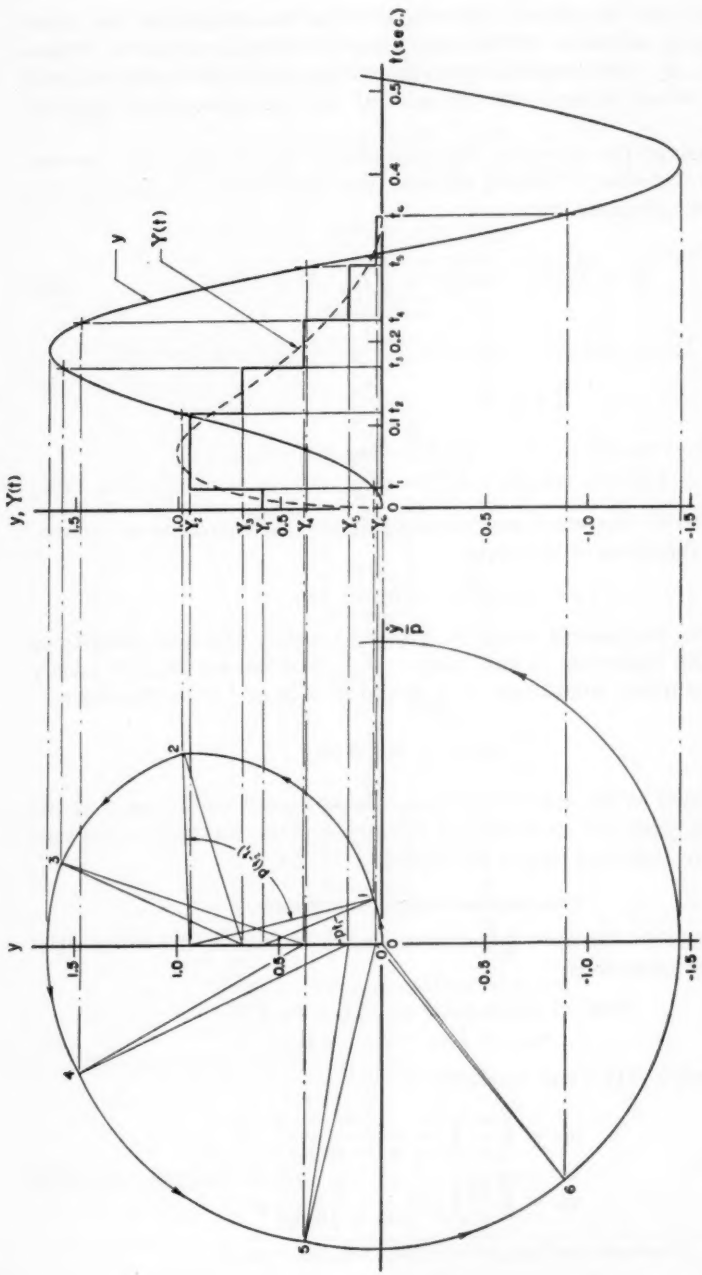

FIG. 2. Graphical solution; single degree of freedom.

1. Forcing function $Y(t)$ is replaced by a stepped approximation; (*b*).
2. Phase trajectory (0–1–2–3–4–5–6——) is constructed in the $\dot{y}/p$, y phase plane; (*a*).
3. Displacement-time curve is determined by direct projection from the phase-plane; (*b*).
(For the assumed natural frequency, $p = 15.2$ radians/second.)

phase-trajectory; in general, the smaller these discontinuities the more accurate is the solution. While the method is related to that of Meissner (11, 12, 13), the graphical procedures bear little similarity to each other. It would appear that for general use the phase-plane method is superior.

It is instructive to write the solutions of Eq. 1 when the forcing function is stepwise.[5] Taking the starting conditions $y = 0$ and $\dot{y} = 0$ at $t = 0$ the solutions are:

1st step,

$$y = Y_1(1 - \cos pt) = \eta(t)_1, \quad 0 \leqq t \leqq t_1 \tag{2a}$$

2nd step,

$$y = Y_1(1 - \cos pt) + (Y_2 - Y_1)[1 - \cos p(t - t_1)] = \eta(t)_2, \quad t_1 \leqq t \leqq t_2 \tag{2b}$$

3rd step,

$$y = Y_1(1 - \cos pt) + (Y_2 - Y_1)[1 - \cos p(t - t_1)], + (Y_3 - Y_2)[1 - \cos p(t - t_2)] = \eta(t)_3, \quad t_2 \leqq t \leqq t_3 \tag{2c}$$

etc. Evidently the resultant vibration is the *superposition* of component free vibrations of the type

$$(Y_n - Y_{n-1})[1 - \cos p(t - t_{n-1})],$$

where a new component must be added to satisfy the new conditions set up at the beginning of each step. It is well known that to satisfy any other starting conditions, $y = y_0$ and $\dot{y} = \dot{y}_0$ at $t = 0$, the terms

$$\frac{\dot{y}_0}{p} \sin pt + y_0 \cos pt$$

must be added to the above solutions. Equations 2 will be used as the basis for showing the extension of the phase-plane method to systems having more than one degree of freedom.

TWO-DEGREE-OF-FREEDOM SYSTEMS

Taking as an example the system shown in Fig. 3, the differential equations of motion are

$$\begin{aligned} m_1\ddot{y}_1 + (k_1 + k_2)y_1 - k_2y_2 &= k_1 \cdot Y(t), \\ m_2\ddot{y}_2 + k_2y_2 - k_2y_1 &= 0. \end{aligned} \tag{3}$$

The amplitude ratios can be shown to be

$$\begin{aligned} \gamma_{\text{I}} &= \left(\frac{a_2}{a_1}\right)_{\text{I}} = \frac{k_2}{k_2 - m_2p_{\text{I}}^2}, \\ \gamma_{\text{II}} &= \left(\frac{a_2}{a_1}\right)_{\text{II}} = \frac{k_2}{k_2 - m_2p_{\text{II}}^2}, \end{aligned} \tag{3a}$$

[5] See also Timoshenko and Young, "Advanced Dynamics," ref. 13.

where the subscripts I and II refer to the natural modes. When $Y(t)$ is given in steps, and when the starting conditions are $y_1 = y_2 = 0$ and $\dot{y}_1 = \dot{y}_2 = 0$, the solutions of the differential Eqs. 3 are

1st step,

$$y_1 = C_I \cdot \eta_I(t)_1 + C_{II} \cdot \eta_{II}(t)_1,$$
$$y_2 = \gamma_I \cdot C_I \cdot \eta_I(t)_1 + \gamma_{II} \cdot C_I \cdot \eta_{III}(t)_1; \quad 0 \lesseqgtr t \lesseqgtr t_1 \qquad (4)$$

2nd step,

$$y_1 = C_I \cdot \eta_I(t)_2 + C_{II} \cdot \eta_{II}(t)_2,$$
$$y_2 = \gamma_I \cdot C_I \cdot \eta_I(t)_2 + \gamma_{II} \cdot C_{II} \cdot \eta_{II}(t)_2; \quad t_1 \lesseqgtr t \lesseqgtr t_2$$

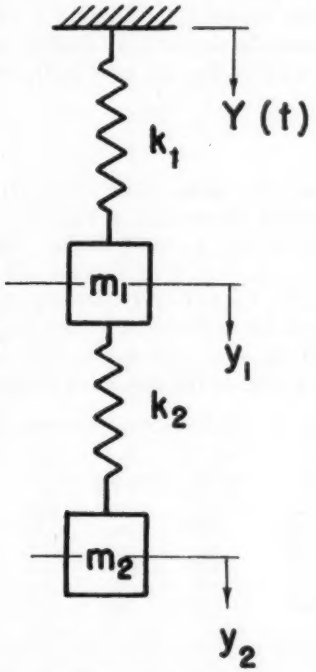

FIG. 3. Two-degree-of-freedom system.
Two masses with elastic coupling.

etc. The constants C_I and C_{II} are

$$C_I = \frac{1 - \gamma_{II}}{\gamma_I - \gamma_{II}}, \quad C_{II} = \frac{\gamma_I - 1}{\gamma_I - \gamma_{II}}, \qquad (4a)$$

while the functions of time are for the 1st step,

$$\eta_I(t)_1 = Y_1(1 - \cos p_I t),$$
$$\eta_{II}(t)_1 = Y_1(1 - \cos p_{II} t);$$

and for the 2nd step,

$$\eta_I(t)_2 = Y_1(1 - \cos p_I t) + (Y_2 - Y_1)[1 - \cos p_I(t - t_1)],$$
$$\eta_{II}(t)_2 = Y_1(1 - \cos p_{II} t) + (Y_2 - Y_1)[1 - \cos p_{II}(i - t_1)]; \quad (4b)$$

etc. Since the displacements y_1 and y_2 consist of two components, one related to the fundamental mode with natural frequency p_I and the other to the second natural mode with frequency p_{II}, we can write

$$y_1 = \phi_I + \phi_{II}, \quad y_2 = \gamma_I \cdot \phi_I + \gamma_{II} \cdot \phi_{II}, \quad (4c)$$

where ϕ_I and ϕ_{II} are the *principal* or *normal* coordinates of the system. Any method which can be used for finding y of the single-degree-of-freedom system can also be applied to finding ϕ_I and ϕ_{II}. Compare $\eta_I(t)_1$ and $\eta_{II}(t)_1$ with $\eta(t)_1$ of Eq. 2*a*, and $\eta_I(t)_2$ and $\eta_{II}(t)_2$ with $\eta(t)_2$ of Eq. 2*b*.

Example

The application of the phase-plane method to a two-degree-of-freedom problem has been illustrated in Fig. 4. Letting $m_1 g = 60$ lb., $m_2 g = 30$ lb., $k_1 = 60$ lb./in., $k_2 = 30$ lb./in., the natural frequencies are $p_I = 13.9$ rad./sec., $p_{II} = 27.8$ rad./sec., and from Eqs. 3*a* and 4*a* $\gamma_I = 2.00$, $\gamma_{II} = -1.00$, $C_I = 0.667$ and $C_{II} = 0.333$. The ground motion $Y(t)$ of Fig. 4(*c*) leads to the phase-plane diagrams for $\eta_I(t) = \phi_I/C_I$ and $\eta_{II}(t) = \phi_{II}/C_{II}$ (Figs. 4(*b*) and 4(*a*)), and upon carrying out the calculations shown in Table A, the resultant displacements y_1 and y_2 can

TABLE A.—*Calculations* to Accompany Fig. 4.*

Step	(1) t, sec	(2) $\frac{\phi_I}{C_I}$	(3) $\frac{\phi_{II}}{C_{II}}$	(4) $0.667\frac{\phi_I}{C_I}$	(5) $0.333\frac{\phi_{II}}{C_{II}}$	(6) y_1	(7) $1.333\frac{\phi_I}{C_I}$	(8) $-0.333\frac{\phi_{II}}{C_{II}}$	(9) y_2
t_1	.025	.035	.13	.023	.043	.066	.047	−.043	.004
t_2	.115	.835	1.795	.557	.598	1.155	1.113	−.598	.515
t_3	.170	1.415	.905	.944	.301	1.245	1.886	−.301	1.585
t_4	.225	1.51	−.715	1.007	−.238	.769	2.013	.238	2.251
t_5	.290	.74	−.21	.494	−.070	.424	.986	.070	1.056
t_6	.350	−.43	1.04	−.287	.346	.059	−.573	−.346	−.919

$$y_1 = C_I\left(\frac{\phi_I}{C_I}\right) + C_{II}\left(\frac{\phi_{II}}{C_{II}}\right). \qquad y_2 = \gamma_I \cdot C_I\left(\frac{\phi_I}{C_I}\right) + \gamma_{II} \cdot C_{II}\left(\frac{\phi_{II}}{C_{II}}\right).$$

$$y_1 = 0.667\frac{\phi_I}{C_I} + 0.333\frac{\phi_{II}}{C_{II}}. \qquad y_2 = 1.333\frac{\phi_I}{C_I} - 0.333\frac{\phi_{II}}{C_{II}}.$$

* It is obvious that the calculations can be avoided if one desires to make the combination directly by means of proportional dividers.

be plotted in Fig. 4(*c*). The procedure may be arranged in various ways; *the essential feature is the independent determination of the normal mode vibrations* ϕ_I *and* ϕ_{II} *and their subsequent combination to give* y_1 *and* y_2.

The application to other spring arrangements and to other forcing functions may be determined readily. It is obvious that to find the constants C_I and C_{II} it is necessary to carry the analysis no further than the solution for the *first* step.

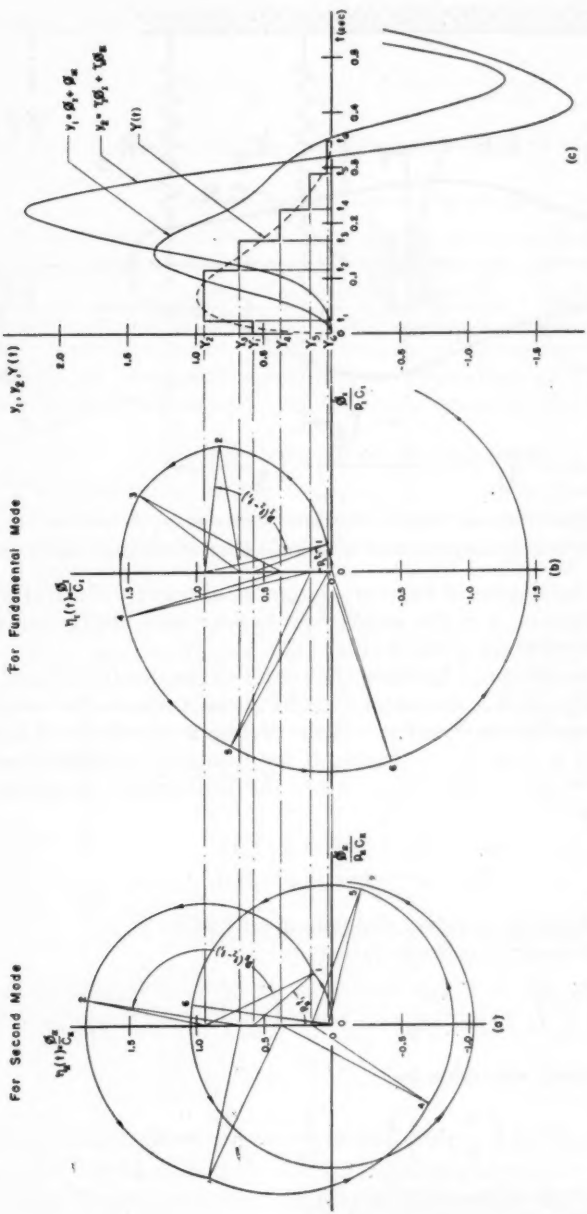

FIG. 4. Graphical solution for two mass, two-degree-of-freedom system.

1. Make stepped approximation of forcing function $Y(t)$; (*c*).
2. Construct fundamental and second mode phase-trajectories; (*b*, *a*).
3. Calculate y_1 and y_2 by Eqs. (4*c*); see Table A.
4. Plot y_1 and y_2 against t in (*c*).

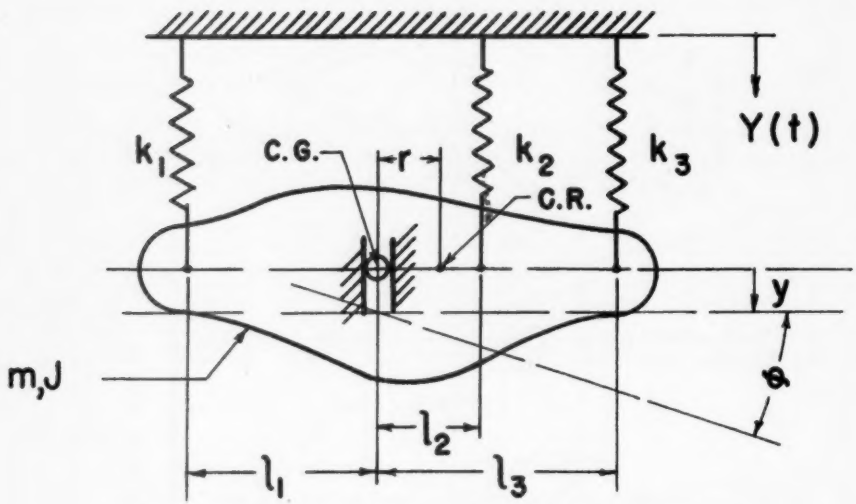

FIG. 5. Single mass, two-degree-of-freedom system with inertia coupling.
Motion in x-direction restrained, as indicated by the vertical guiding at the center of gravity.

One other two-degree-of-freedom system is sufficiently illustrative to warrant its inclusion; it is the single mass system with inertia coupling between the coordinates y and θ (Fig. 5).

In Fig. 5 the distance r between the center of gravity (C.G.) and the center of rigidity (C.R.), or center of static twist,[6] effects the coupling between the coordinates θ and y. If the resultant translational spring constant is $k = k_1 + k_2 + \cdots k_n$ and if the resultant rotational spring constant is $\kappa = k_1 l_1^2 + k_2 l_2^2 + \cdots k_n l_n^2$, the differential equations of motion become

$$\begin{aligned} m\ddot{y} + ky + kr\theta &= k \cdot Y(t), \\ J\ddot{\theta} + \kappa\theta + kry &= kr \cdot Y(t), \end{aligned} \tag{5}$$

where the existence of coupling depends upon $r \neq 0$.

The natural mode amplitude ratios are

$$\gamma_{\mathrm{I}} = \left(\frac{a_\theta}{a_y}\right)_{\mathrm{I}} = \frac{-kr}{\kappa - Jp_{\mathrm{I}}^2}, \quad \gamma_{\mathrm{II}} = \left(\frac{a_\theta}{a_y}\right)_{\mathrm{II}} = \frac{-kr}{\kappa - Jp_{\mathrm{II}}^2}, \tag{5a}$$

while the frequency equation is

$$p^4 - \left(\frac{k}{m} + \frac{\kappa}{J}\right)p^2 + \frac{k}{m}\cdot\frac{\kappa - kr^2}{J} = 0. \tag{5b}$$

The solution of the differential equations, when the ground motion is

[6] A *static* force applied at the center of static twist causes *no rotation*.

stepwise, is the same as Eqs. 4 except that the constants are

$$C_{\mathrm{I}} = \frac{-\gamma_{\mathrm{II}}}{\gamma_{\mathrm{I}} - \gamma_{\mathrm{II}}}, \quad C_{\mathrm{II}} = \frac{\gamma_{\mathrm{I}}}{\gamma_{\mathrm{I}} - \gamma_{\mathrm{II}}}. \tag{5c}$$

The graphical procedure is in general the same as for the two mass system.

SYSTEMS HAVING n DEGREES OF FREEDOM

It is obvious that the method can be applied to systems having any number of degrees of freedom, but when n is greater than two the constants $C_{\mathrm{I}}, C_{\mathrm{II}}, \cdots C_n$ may become complicated. There will then be n equations of the type (4), each containing n terms. While n phase planes theoretically are required, it frequently is not necessary to evaluate all of the terms since some of them, depending upon the relationship of the forcing frequencies to the natural frequencies, will be insignificant.

SYSTEMS WITH DISTRIBUTED PARAMETERS

The application to the transient flexural vibration of beams can readily be shown. Considering a uniform, simply supported beam of span-length l, flexural rigidity EI, and mass per unit length μ, loaded

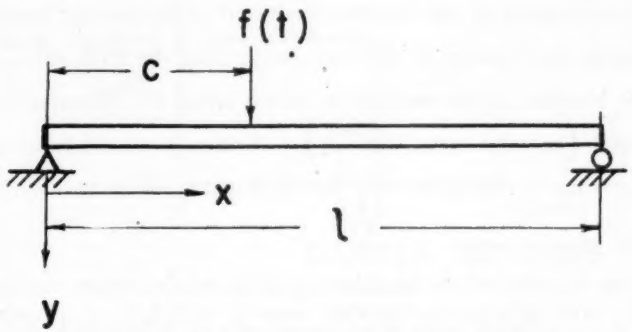

FIG. 6. Simply supported beam carrying a concentrated force.

by a concentrated force $f(t)$ as shown in Fig. 6, the solution[7] for the *first step* with a start from rest is:

$$q_i = \frac{2l^3}{i^4\pi^4 EI} F_1 \sin\frac{i\pi c}{l}(1 - \cos p_i t), \quad 0 \leqq t \leqq t_1,$$

where q_i is the generalized coordinate relating to the i^{th} natural mode and where the corresponding circular natural frequency is $p_i = (i^2\pi^2/l^2)\sqrt{EI/\mu}$.

[7] Easily derived by reference to Timoshenko, "Vibration Problems in Engineering," p. 348, ref. 14.

The deflection y at any location x is

$$y = \sum_{i=1,2,\cdots}^{\infty} q_i \sin \frac{i\pi x}{l}$$

$$= \frac{2F_1 l^3}{\pi^4 EI} \sum_{i=1,2,\cdots}^{\infty} \frac{1}{i^4} \sin \frac{i\pi c}{l} \cdot \sin \frac{i\pi x}{l} \cdot (1 - \cos p_i t), \qquad (6)$$

where the terms $\frac{2F_1 l^3}{\pi^4 EI}(1 - \cos p_i t)$ correspond to the functions $\eta_{\mathrm{I}}(t)_1$, $\eta_{\mathrm{II}}(t)_1$, etc., for the lumped parameter system (Eqs. 4 and 4*b*), and where the dimensionless quantities $\frac{1}{i^4} \cdot \sin \frac{i\pi c}{l} \cdot \sin \frac{i\pi x}{l}$ relate to the constants C_{I}, C_{II}, $\gamma_{\mathrm{I}} C_{\mathrm{I}}$, $\gamma_{\mathrm{II}} C_{\mathrm{II}}$, etc. (Eqs. 4 and 4*a*).

The flexural stress σ can also be determined; it is

$$\sigma = \frac{M_z}{Z} = -\frac{EI}{Z} \frac{\partial^2 y}{\partial x^2} = \frac{2F_1 l}{\pi^2 Z} \sum_{i=1,2,\cdots}^{\infty} \frac{1}{i^2} \sin \frac{i\pi c}{l} \cdot \sin \frac{i\pi x}{l} (1 - \cos p_i t), \qquad (7)$$

where Z is the section modulus of the beam.

It is well known that the number of terms, and consequently the number of necessary phase-planes, required to express y or σ sufficiently accurately depends on the frequency content of the forcing function as well as upon the location of the force as affecting the terms $\sin \frac{i\pi c}{l}$, and upon the location of the section at which stress or deflection is to be determined $\left(\text{see the term, } \sin \frac{i\pi x}{l}\right)$. Under some conditions, satisfactory results are obtained with not more than one or two terms.

Example

Let the location of the load be $c = l/2$, and determine the stress at $x = l/2$. The symmetrical modes alone ($i = 1, 3, 5, \cdots$) are excited by this location of the load and we have for the first step:

$$y = \frac{2F_1 l^3}{\pi^4 EI} \sum_{i=1,3,5,\cdots}^{\infty} \frac{1}{i^4} (1 - \cos p_i t), \qquad (6a)$$

$$\sigma = \frac{2F_1 l}{\pi^2 Z} \sum_{i=1,3,5,\cdots}^{\infty} \frac{1}{i^2} (1 - \cos p_i t), \qquad (7a)$$

where $0 \leqq t \leqq t_1$.

In order to be definite, assume a 15 in. by 6 in. I-beam having the following properties: $l = 240$ in., $Z = 81.2$ in.^{3}, $I = 609$ in.^{4}, $\mu = \frac{60.8}{12 \times 386} = 0.0131 \frac{\text{lb.} \times \text{sec.}^2}{\text{in.}^2}$, $E = 30 \times 10^6 \frac{\text{lb.}}{\text{in.}^2}$. The circular

natural frequencies for modes 1, 3 and 5 are then

$$p_1 = \frac{\pi^2}{240^2}\sqrt{\frac{30 \times 10^6 \times 609}{0.0131}} = 202 \frac{\text{radians}}{\text{second}},$$

$$p_3 = 3^2 \times p_1 = 1818 \frac{\text{radians}}{\text{second}}, \quad p_5 = 5^2 \times p_1 = 5050 \frac{\text{radians}}{\text{second}},$$

and the corresponding natural periods are $T_1 = 0.0311$, $T_3 = 0.00346$, $T_5 = 0.00124$ sec. Two examples have already been given in which the forcing function has been represented by a sequence of steps; in this case, for simplicity, we will assume a rectangular step pulse as shown in Fig. 7.

Since the duration of the pulse t_1 has been assumed equal to one-half the third natural period T_3 we know at once that the third natural mode will be excited to a considerable extent. Furthermore, the fundamental mode will make an important contribution, and since the *stress* series (7*a*) converges much less rapidly than the *deflection* series (6*a*) (compare

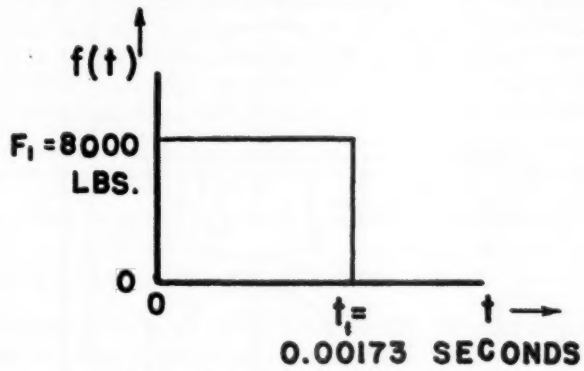

FIG. 7. Rectangular step pulse.

the factors $1/i^2$ and $1/i^4$) we can estimate that the fifth mode should also be taken into account. Rewriting Eq. 7*a*, and limiting the series to terms 1, 3 and 5, we have

$$\sigma \approx \sigma_1 + \sigma_3 + \sigma_5 = \frac{2F_1 l}{\pi^2 Z}(1 - \cos p_1 t) + \frac{1}{3^2}\cdot\frac{2F_1 l}{\pi^2 Z}(1 - \cos p_3 t) + \frac{1}{5^2}\cdot\frac{2F_1 l}{\pi^2 Z}(1 - \cos p_5 t), \quad (8)$$

where $0 \leqq t \leqq t_1 = 0.00173$.

An equation may also be written for the next time era, $t \geqq t_1$, but the equation for the first era will enable us to start the graphical solution. Comparing Eq. 8 with Eq. 2*a*, which describes the first step for the

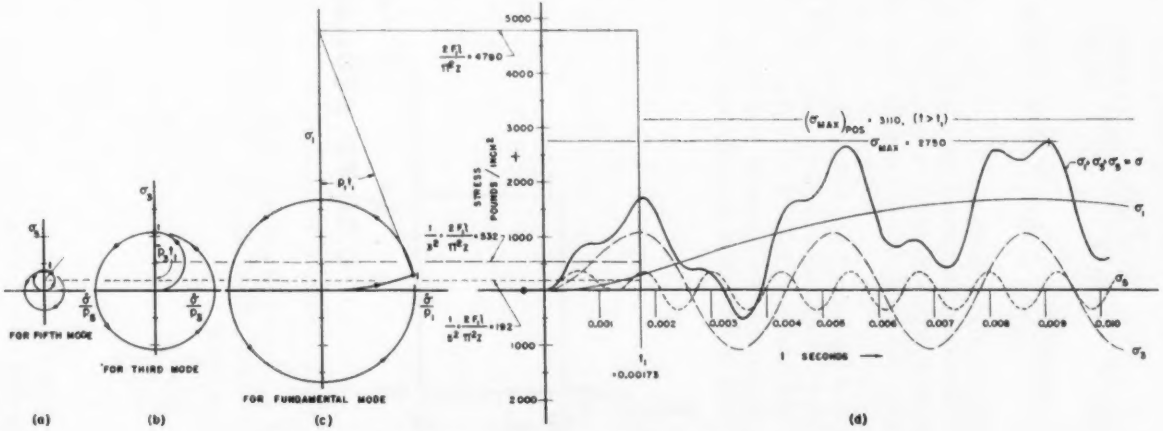

FIG. 8. Graphical solution for uniform single-span simply supported beam.

Dynamic stress when beam is excited by a rectangular force pulse applied at mid-span.

single-degree-of-freedom system, it is apparent that the remaining problem is to set up the independent phase-planes for modes 1, 3 and 5, where the coordinates of the planes are now *stress* and *rate of change of stress*, rather than displacement and velocity.

In the example for the two-degree-of-freedom case (Fig. 4) the forcing function $Y(t)$ was plotted and both phase-trajectories were constructed by direct projection from the single $Y(t)$ plot. It was then necessary to multiply the ordinates of the trajectories by the appropriate constants, C_{I}, C_{II}, etc., before combining the natural mode components to give the resultant vibrations y_1 and y_2. An alternate method will be employed here in which a *separate* forcing function diagram is related to each phase-plane (see Fig. 8), the ordinates of the forcing diagrams being proportional respectively to $1/1$, $1/3^2$, and $1/5^2$, that is, to $1/i^2$. The alternate method has two advantages: (1) the ordinates of the trajectories can be combined directly, as in Fig. 8(*d*), without computation, and (2) the phase-planes show at once the relative importance of the natural mode vibrations.

It is obvious that the ordinate labeled $\sigma_{\max}$ in Fig. 8(*d*) is not necessarily the absolute maximum stress since the analysis has been carried in time only as far as the first maximum of the fundamental term. The possible absolute maximum stress will of course be equal to the arithmetic sum of the maxima of the three components involved; this is labeled $(\sigma_{\max})_{\mathrm{pos}}$ and is approximately 13 per cent higher than $\sigma_{\max}$.

The stress due to a statically applied load of 8000 lb. at the center of the beam is $\sigma_{st} = 5910 \frac{\text{lb.}}{\text{in.}^2}$; the ratio of maximum dynamic stress to static stress is therefore $\frac{\sigma_{\max}}{\sigma_{st}} = \frac{2750}{5910} = 0.465$.

The application to other cases, for example, the effect of a ground acceleration or of an air blast on a cantilever beam (an idealized, tall building), can also be made.

Acknowledgment

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NOTES FROM THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

CLASSIFICATION OF GRINDING WHEELS

Modifying a surface by rubbing it with a substance made up of hard sharp particles is a very ancient process that is still in such general use today that perhaps not a single industry is independent of this process for its production operations or for the tools used in its production operations. Certain factors upon which the grinding process depends—such as hardness of the grain, resistance of the grain to removal from its supporting medium, and the speed and pressure applied to the grinding operation—have been apparent to manufacturers and users of grinding wheels for many years.

Present empirical techniques have established a tenuous relationship between the production factors and the use. These factors include grain size, shape, and composition; percentage of grain to binder; nature of binder; pressed density; and vitrification characteristics such as firing time, temperature, and atmosphere. Classification and control of these factors is a primary consideration of the grinding wheel industry.

In 1944, the Grinding Wheel Institute took the first step toward adopting a standard grading system when its members promulgated a Standard Marking System for Grinding Wheels. Yet today, identical wheels of different manufacturers may be marked differently, partly because identification symbols have not attained universal physical significance; moreover, not all manufacturers use the Standard Marking System.

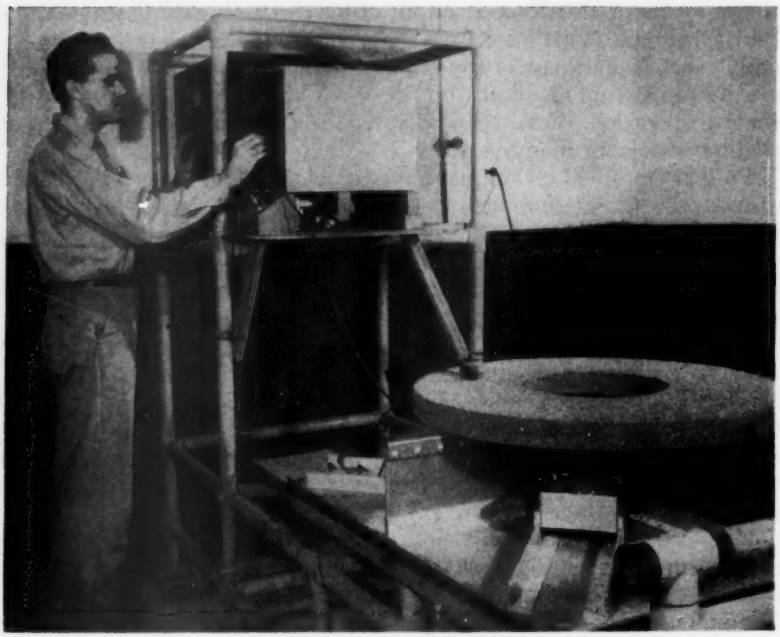
The second step toward standardization was the use of sonic testing for measuring natural frequency of vibration of grinding wheels. At least four manufacturers have adopted sonic testing. One of these, The Simonds Abrasive Company, sponsored the development, by The Franklin Institute Laboratories, of a sonic testing device. The sonic tester shown in the figure was constructed by the Electrical Engineering Group. The specimen wheel is excited into vibration by the sound from loudspeaker drivers, and its vibration frequency is transmitted by a vibration pickup to the measuring circuit and oscilloscope. However, determining natural frequency is an insufficient, though necessary, condition for deriving a grade index; it alone is not an infallible indication of grade because it is not independent of wheel dimensions.

The third step was the development and validation of a mathematical expression for grade. Franklin Institute investigators have proposed a grade number, G, which may be calculated when easily

measured quantities are put into the following equation:

$$G = Cf\frac{D^2}{t} = \sqrt{\frac{1}{k}\frac{E}{\rho_m}}.$$

Here, f is the natural frequency of the wheel, D is the outer diameter, t is the thickness, C is a correction for the ratio between inner and outer diameters, E is a modulus of elasticity, ρ_m is the mass density, and k is a composite of appropriate coefficients. The expression for the modulus, E, is identical in form to expressions for the modulus of elasticity of a



The Sonic Tester. A Simonds Abrasive Company employee is using the tester to determine the natural frequency of a grinding wheel.

thin circular plate. The expression for the grade number, G, is proportional to the velocity of sound through the material. This grade number was proposed as an index for grade because it requires one less measurement for its determination than does the modulus. This equation has been validated for wheels whose thicknesses do not exceed 1/7 of their diameters. Further experimental and mathematical work should yield a satisfactory modification of the above equation to account for form factors for which thin plate theory is insufficient.

The fourth step is a continuing investigation of the relations that exist between this new grade index and the compositional variables taken one at a time. Results suggest that the grade number does not vary with different crystalline forms of the same grit material, or with grit size. On the other hand, grade index is a function of the grit-to-bond ratio, the pressed density, and the specific bond material. The latter physical factors are not accounted in the Standard Marking System, but they are represented by grade symbol, structure symbol, bond type and bond symbol in various ways by various manufacturers. Adoption of a standard marking system for all the variables in grinding wheel manufacturing together with uniform use of the sonic test method could be of vital importance to all users of grinding wheels in making possible the interchangeability of brands. Such a standardization would have to depend, of course, upon the willingness of grinding wheel manufacturers to divulge with complete frankness all data relating to their products.

What has already been done indicates the need for a further research program with the objective of obtaining additional information, which will lead to a more precise classification of grinding wheels. This program will probably encompass (*a*) an investigation of the conditions necessary for establishing a standard grading system, (*b*) an investigation of the relationships that exist among grinding action, wheel wear, controls of the grinding process, and grinding wheel specifications for a wide variety of metals, and (*c*) an evaluation of the relative merits of different sonic testing instruments and the possibility of developing machinery for automatic grading.

WALTER W. FELTON

AN ADVANCED TIME SCALE ANALOG COMPUTER*

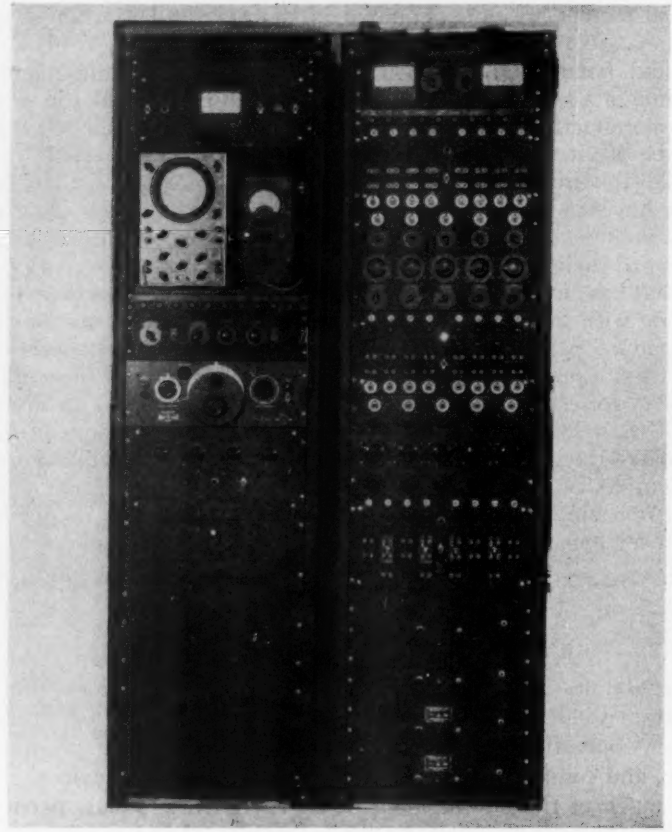
Regulatory and control systems are becoming more and more important to all of us. In industry, in the home, in transportation, in military operations—nearly everywhere we look—our productivity, safety, and comfort are increased by these ubiquitous devices. In the past, much of the development of these control systems, particularly the more complicated ones, has been on an empirical or trial-and-error basis, principally because the mathematical expressions that are involved in any rational approach to their design are complex and unwieldy.

The Franklin Institute Laboratories have designed and constructed an "advanced time scale analog computer" capable of solving high-

* This computer was developed for the Bureau of Ordnance, Department of the Navy, under Contract No. NOrd 10625 with The Franklin Institute Laboratories for Research and Development.

order differential equations, thereby facilitating the analysis or synthesis of complicated control systems. This work was done by the Electrical Engineering Group.

Because this computer is to solve problems encountered in the designing of industrial controllers and servomechanisms for military



The Advanced Time Scale Analog Computer is shown here in front view. At top left are the oscilloscope and voltmeter used for solution display.

application, it bears certain features not ordinarily found in general-purpose computers. In general, this computer will solve differential equations, of the first degree and up to approximately the tenth order, with constant coefficients. The salient feature of this computer is its advanced time scale, the chief advantage being that the solution to a problem can be conveniently displayed. Whereas the solutions offered

by a computer functioning on a 1:1 time scale must be graphically recorded, by applying forcing functions periodically—about 20 times per second—an oscilloscope is used for displaying the solutions yielded by the advanced time scale analog computer. A secondary advantage of incorporating an advanced time scale is that it enables this device to perform computations more rapidly than a computer that has a direct or unity time scale. Specifically, this computer operates normally on a 100:1 scale (100 times more rapid than if it were to operate on a 1:1 scale), and can operate more, or less, rapidly if the time constants within the device are recalibrated. Accuracy, however, is sacrificed if it is called upon to function on a time scale advanced more than 100:1.

There are three signals, or forcing functions, that can be used for the computer input: a sine wave, square wave (step function), or a repetitive pulse of variable width. A voltmeter and phase meter measure frequency response when the sine wave input is employed. An oscilloscope is provided for observing the transient responses to the step function and the pulse, which are photographed for permanent record. The basic computing device is the negative-feedback d-c. amplifier; there are twenty-four of these amplifiers which may be plugged into the computer rack. In addition to the d-c. amplifiers, which are used for linear operations, the computer rack contains two limiters, one inert-zone component, and one hysteresis component, which are used for nonlinearities.

BRUCE B. YOUNG

NOTES FROM THE NATIONAL BUREAU OF STANDARDS*

SPONTANEOUS IGNITION OF DECOMPOSING NITRATE FILM

Investigations by the National Bureau of Standards have shown that spontaneous ignition of cellulose nitrate motion picture film can occur when such film is in an advanced stage of decomposition. Prior to this work it was generally believed that nitrate film would not ignite spontaneously at temperatures ordinarily encountered in a film vault. Tests made by A. C. Hutton of the NBS Fire Protection Laboratory and conducted in cooperation with the National Archives have provided the necessary information to prevent reoccurrence of the severe fire losses to film and storage facilities that have been experienced in recent years.

In New York City and adjacent areas during the abnormally hot summer of 1949 numerous fires occurred involving cellulose nitrate motion picture films. These fires started in processing and reclamation plants and in film storage facilities. Losses, other than those of real property, were great, the majority of the films destroyed being original negatives and master copies, some dating back to the "silent era." In studying storage conditions the National Archives and NBS engineers found no evidence that the fires were due to the negligence of personnel or the careless use of cigarettes or matches; instead, the fires appeared to have originated through the spontaneous ignition of deteriorated nitrate films.

At the request of the National Archives, therefore, the National Bureau of Standards instituted an investigation of spontaneous ignition as an inherent hazard with nitrate film. Samples in various stages of decomposition were supplied by the National Archives for the purpose of simulating conditions which may have prevailed at the fire locations. These samples were stored in a special chamber, the temperature of which was controlled and recorded. Each film was packed in an individual can which was in turn wrapped in mineral wool to retain the heat of the exothermic decomposition reaction. The ambient temperature in the chamber was intially 95° F. and, at intervals, was increased by small increments, but always maintained below that of the reacting film.

At a chamber temperature of 106° F., one roll of film in the more advanced stage of decomposition was found to be increasing in temperature at an accelerating rate. On the 17th day of storage, with the

* Communicated by the Director.

chamber temperature still at 106° F., ignition of the film occurred. Its temperature at the time had reached 140° F. Other rolls of film under the same test had slower rates of temperature increase. With the chamber held at 120° F., another case of spontaneous ignition occurred when a roll ignited after self-heating to 150° F.

Self-ignition temperature is dependent upon a number of factors and therefore was not the same for any two samples. The lowest temperature leading to ignition was 106° F. Because the number of samples investigated was small, it is doubtful whether this is the lowest temperature at which a reel of deteriorating film will self-ignite.

The results obtained in the NBS tests indicate that good film does not self-ignite at ordinary storage temperatures. In one of the government film depositories large quantities of cellulose nitrate film have been stored in standard vaults in which the temperatures are maintained at about 70° F. by an air conditioning system. Several inspections of film in these vaults did not reveal evidence of serious film decomposition. This indicates that relatively low temperatures will materially decrease the possibility of a fire by spontaneous ignition and at the same time preserve the film for its intended purpose.

The logical approach to safe storage is the removal of all film showing signs of deterioration. Such film can readily be found by scheduled inspections of stored film stocks. Inspection personnel should be trained to recognize decomposing film by appearance, and to classify its condition according to the following categories. In the first stage of deterioration the photographic portion usually shows an amber discoloration with fading of the picture image. In the second stage, the emulsion becomes adhesive and the film convolutions tend to stick together during unrolling. Film in the third-stage of deterioration has portions which are soft, contain gas bubbles, and emit a distinctive noxious odor. In the fourth stage, the entire film is soft; its convolutions are welded into a single mass, and frequently its surface is covered with a viscous froth. The same noxious odor, only stronger, is in evidence. In the fifth and final stage, the film mass degenerates partially or entirely into a brownish acrid powder.

Deteriorated film in the first and second stages is photographically reproducible. When the subject matter is important, the film can be copied and the original destroyed. If the material is not valuable, the film should be destroyed at once. Adhesiveness prevailing in deteriorating film often causes the emulsion to become detached from the base while unrolling. Generally, this can be prevented by slowly unrolling the film in a bath of carbon tetrachloride under precise laboratory controls and in an adequately ventilated area. In the third stage, only small portions of the film may be reproducible. When of sufficient value, such portions should be separated and copied; the original should then be destroyed. Film in the fourth and fifth stages

is photographically worthless and should be destroyed at once without further consideration.

During the initial inspection of film storage facilities it is quite possible that a relatively high proportion of film in advanced stages of decomposition may be found. The opening of cans containing such film may liberate quantities of noxious and toxic gases into the working area. Personnel exposed to these gases often experience nausea, headache, and other unpleasant symptoms if the ventilation is inadequate. Inspection personnel should therefore be given periodic rest periods in fresh air.

When films in the third, fourth, and fifth stages of decomposition are designated for disposal, they should be submerged immediately in water-filled drums, carried to a remote, uninhabited area approved by fire authorities, and destroyed by burning. The area or ground on which the film is to be burned should be free of brush, grass, leaves, and combustible litter. Burning should be confined to batches of not more than 25 pounds because the heat from larger amounts of film creates a strong updraft which may bear fragments of burning film considerable distances, thus endangering neighboring properties. Under no circumstances should films be burned in an inhabited area or within a building. The rapid production of gases during burning makes it extremely dangerous, particularly if the film is burned in a furnace or confined space. During test fires in a well vented vault, engineers of the Interagency Advisory Committee for Nitrate Film Vault Tests recorded pressures as high as 18 psi. No ordinary furnace structure could withstand such pressure; its breeching would fail, thus filling the furnace room with flames and poisonous gases.

NOTE: For an earlier report on this work, see "Spontaneous Ignition of Decomposing Cellulose Nitrate Film," by James W. Cummings, Alvin C. Hutton, and Howard Silfin, *Journal of the Society of Motion Pictures and Television Engineers*, Vol. 54, No. 3, March, 1950, p. 268.

BEAM INTENSIFICATION IN A HIGH-VOLTAGE OSCILLOGRAPH

A new technique developed by J. H. Park of the National Bureau of Standards increases the "writing speed" of a high-voltage oscillograph to three-fourths the velocity of light. High intensification of the electron beam is obtained momentarily by superposing a steeply rising voltage pulse on the steady voltage applied to the discharge tube of the oscillograph.[1] The resultant increase in the intensity of the trace makes writing speeds up to 9100 inches per microsecond easily visible. These high writing speeds can be used to study rapidly varying electrical surges, such as are caused by lightning discharges, and to learn more about the insulation breakdown the surges produce.

[1] For further details, see "A Fifty-Fold Momentary Beam Intensification for a High-Voltage Cold-Cathode Oscillograph," by John H. Park, *J. Research NBS*, Vol. 47, p. 87, 1951, RP 2231.

Insulation breakdown due to lightning discharge is a frequent cause of power outages and failure of electrical equipment. Thus, for development of insulation designs, as well as for routine tests on high-voltage components, most manufacturers of high-voltage equipment now maintain surge generators which enable them to produce in the laboratory electrical surges having the same voltage and current magnitudes as those occurring on transmission lines as a result of natural lightning. During a thunderstorm an electrical system may experience surges rising to a million volts or a hundred thousand amperes in less than one millionth of a second. For measurement of such rapid changes in current or voltage when they are artificially produced, special high-voltage cathode-ray oscillographs are used in which a cold-cathode discharge tube is the source of the electron beam. Part of the beam passes through a small hole in the center of the anode of the discharge tube into the main chamber of the oscillograph. Here the electrons pass through a beam trap, focusing coils, deflecting and sweep plates and finally strike a photographic film or fluorescent screen. A pulse of increasing voltage applied to the sweep plates moves the electron beam horizontally across the film, providing a time axis. The voltage pulse to be studied, after being reduced in magnitude by a suitable divider, is applied to the deflection plates and causes deflection of the beam perpendicular to the time axis. This deflection, in combination with the sweep, leaves a trace on the film which in effect is a plot of voltage against time for a particular surge. A corresponding plot of current against time can be obtained by using a shunt in place of the divider. In order to have a readable photographic record of the steeply rising front of the surge, it is necessary to use a very high-intensity electron beam for recording fast phenomena. Several methods have been used to increase the beam intensity, and thus the writing speed, of this type of oscillograph. For example, some workers have used prefocusing coils around the discharge tube, others have reshaped the electrodes or employed different gases in the discharge tube. None of these methods, however, has been entirely successful, and until now the normal writing speed of the instrument has been only about 200 in./μsec. As part of a general program of basic instrumentation sponsored at NBS by the Office of Naval Research, the Office of Air Research, and the Atomic Energy Commission, the Bureau therefore undertook to develop a more effective technique for intensifying the beam. The resulting method increases the beam intensity by as much as 50 times the steady value.

In the NBS method, a momentary pulse having a peak value of about 2000 volts is superposed on the steady d-c voltage of 50 kv normally applied to the discharge tube. The pulse should be of short duration, down to 5 μsec, and it must produce a sudden increase in the voltage across the tube in 0.5 μsec or less. This sudden change in

voltage, even though it is only 2 per cent of the steady voltage across the discharge tube, momentarily disrupts equilibrium conditions in the tube, producing a greatly intensified electron beam for about 2 μsec. The increased beam current lasts for such a short time that it does not appreciably increase the heat developed in the discharge tube or "burning" at the cathode. However, its duration is such that by careful synchronization with the start of the sweep it can be used to obtain the greatly intensified beam for total sweep times of 1 μsec or less as desired.

Two principal methods for applying the pulse have been developed and used by NBS. In one method a current pulse is passed through a resistor placed between the anode and the ground return lead. This causes a similar voltage pulse across the discharge tube, which results in a sharp increase in the intensity of the electron beam. In the other method, the cathode is connected to one terminal of a small high-voltage capacitor, and the other terminal is connected to ground through a resistor. By means of the steady direct-current voltage on the cathode, this capacitor is charged to 50 kv, and when a current pulse is passed through the resistor, the cathode voltage is immediately changed by the drop through the resistor. This produces a very rapid change in the intensity of the beam.

A method of synchronizing the start of beam intensification with the start of the sweep has been devised by NBS and used successfully with sweep speeds up to 60 in./μsec. These fast sweeps were used to obtain records of the voltage oscillations occurring when the deflecting plates were short-circuited after being charged to a high voltage. Although this procedure deflected the electron beam from the top to the bottom of the film record in about the shortest time possible, a readable trace was still recorded on the film, and this trace was found to correspond to a "writing speed" of 9100 in./μsec (three-fourths the velocity of light).

Writing speeds greater than the speed of light could probably be obtained by the NBS technique if the deflecting system of the oscillograph were designed with this objective in mind. Since the current in the discharge tube is maintained at a low steady value except for the very short time required to obtain the record, the problems of beam adjustment and life of cathode become of minor importance. In addition to its uses with the high-voltage oscillograph, the new NBS method should provide a useful tool for research in atomic physics wherever an electron beam of high momentary density is required.

THE FRANKLIN INSTITUTE

MINUTES OF THE STATED ANNUAL MEETING

January 16, 1952

The Stated Annual Meeting of The Franklin Institute was held on Wednesday, January 16, 1952, in the Lecture Hall of The Franklin Institute. The President, Richard T. Nalle, called the meeting to order at 8:15 P.M. Approximately 160 persons attended.

The President announced that the Minutes of the Stated Monthly Meeting for December are being printed in full in the January issue of the JOURNAL OF THE FRANKLIN INSTITUTE and will be presented for approval at the February meeting.

He also announced that the Annual Report of the Board of Managers will be presented at a meeting in the Spring after receipt of the auditor's report.

The Secretary reported the following elections to membership for the month of December:

Active	24
Associate	28
Student	29

and reported further that total Institute membership as of December 31, 1951, was 6,246.

The President called for the report of the tellers appointed in accordance with the By-Laws to count the votes for the eight Managers to be elected. Dr. George S. Crampton, Chairman, reported that a total of 842 ballots were cast, of which 823 were legal and 19 defective, and that the several nominees received votes as follows:

Henry B. Bryans	823	W. H. Fulweiler	822
Francis J. Chesterman	821	Wilfred D. Gillen	823
James Creese	822	Marshall S. Morgan	822
Rupen Eksergian	819	Edward Warwick	822

The President declared that the above members were hereby elected Managers of the Institute for a term of three years. He thanked Dr. George S. Crampton, Dr. Joseph S. Hepburn and Mr. Penrose Hoopes for their services as tellers.

The Secretary read the following report of the trustees of the Elliot Cresson Fund:

ELLIOT CRESSON FUND

Report of the Trustees to the
Annual Meeting of The Franklin Institute
January 16, 1952

The deed of gift under which Elliot Cresson in 1848 gave $1000 to two trustees, the income of which was to furnish medals to be awarded by The Franklin Institute, provided that the trustees should present to the annual meeting of The Institute each year a report showing the principal of the fund and its income and expenses during the preceding year. This report is submitted in accordance with such provision.

Principal of the Fund (representing the original $1000 plus transfers thereto from Unexpended Income and profit from disposition of investments)		$4,304.73
Invested as follows:		
$4000 U. S. Treasury 2½% bonds, due 6/15/1962–67 at book value	$4,168.43	
Cash in Western Saving Fund Society	136.30	
	$4,304.73	
Income of the Fund for 1951:		
Interest on bonds (less amortization)	130.22	
Interest on bank balance	2.55	132.77
Expenses:		
Insurance on medal dies for a period of three years beginning January 29, 1951	39.25	
Three certified copies of Deed of Trust	18.00	57.25
Unexpended income for the year		75.52
Unexpended income at January 1, 1951		2,253.77
Unexpended income at December 31, 1951		$2,329.29

Invested as follows:

$2000 U. S. Treasury 2½% bonds, due 6/15/1962-67 at book value	2,084.64
Cash in Fidelity-Philadelphia Trust Company	244.65
	$2,329.29

HENRY B. ALLEN
JOHN FRAZER } *Trustees*

The President announced that Major General Alfred B. Quinton, Jr., scheduled to speak that evening, was ill. He then introduced Brigadier General Merle H. Davis (Chief, Ammunition Branch, Industrial Division, Office of Chief of Ordnance, Washington, D. C.). General Davis read General Quinton's paper on "Army Ordnance Today" in part, interspersing interesting comments from his own experiences and observations since his enlistment in the Army in 1917. (General Quinton's paper will be published in a future issue of the JOURNAL.)

General Davis was tendered a rising vote of thanks as the meeting adjourned.

HENRY B. ALLEN,
Secretary

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, JANUARY 16, 1952

ACTIVE FAMILY

Manuel M. Album, D.D.S.
Charles B. Beck
Chalmer G. Kirkbride

ACTIVE

Samuel T. Brinton
Robert E. Burroughs
Edward L. Campbell, Jr.
Walter M. Faust
L. P. Fessler
Matthew G. Fox
Robert G. Goodyear
Theodore P. Gorsuch
Frank K. Kelemen
Vincent Kling
Joseph Kohn
John S. Newbold
C. M. Reign
Albert Sokolic
Robert D. Spiegle
J. Harlow Vrooman
C. L. Winder

ACTIVE NON-RESIDENT

Robert E. L. Keller
Irving J. Lieberman

NECROLOGY

Charles Merrick Gay '33
Jennings Hood '43
James G. Vail '16
J. R. Wyatt '23

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in the JOURNAL within the next few months:

NORINDER, HARALD: Investigation of Resistance and Power in Experimental Lightning Discharges.

SMITH, J. J. AND P. L. ALGER: The Use of the Null-Unit Function in Generalized Integration.

KU, Y. H.: Resume of Maxwell's and Kirchhoff's Rules for Network Analysis.

BLADEL, JEAN VAN: Field Expandability in Normal Modes for a Multilayered Rectangular or Circular Wave-Guide.

SILBERSTEIN, LUDWIK: Generalities Concerning "Simple" and Mixed Photographic Emulsions as Manifested by Their Characteristics.

SAIBEL, EDWARD: Buckling of Continuous Beams on Elastic Supports.

ZADEH, LOFTI A.: A General Theory of Signal Transmission Systems.

MOON, PARRY AND DOMINA EBERLE SPENCER: Separability in a Class of Coordinate Systems.

MUSEUM

The oldest fire engine in Philadelphia will be 222 years old in April, and the second is its junior by only five years. Both are on display in our Museum. Old as these are, neither was the first fire engine owned by the city of Philadelphia for, in the *Minutes of the Common Council* of December, 8, 1718, we learn that the City Treasurer was ordered to pay Abraham Bickley the sum of fifty pounds for a fire engine. The money was raised from fees collected by the city employed chimney sweeps. Bickley's fire engine cannot have been a great success for in April, 1730, the Common Council ordered three new fire engines from London at a cost of 50, 35, and 20 pounds respectively. These engines were made by Richard Newsham of Cloth Fair, near Smithfield, London. Newsham, who a writer in the *London Magazine* for 1752 declares gave "a nobler present to his country than if he had added provinces to Great Britain," must have been an oddity, for he was originally a pearl button maker who described himself as an engineer.

In a broadside describing his fire engines Newsham states that he "makes the most useful and convenient Engines for quenching FIRES, which carry a constant Stream with great Force, and yet, at Pleasure, will water Gardens with small Rain. The largest size will go through any Passage one Yard wide, in compleat working Order, without taking off, or putting on anything, which is not to be parallel'd by any other Sort whatsoever," the other sorts being contemptuously dismissed as "cumbersome Squirting Engines" in Gothic letters, presumably to indicate their antiquity.

One of the engines in the Museum still retains traces of colored decoration and, barely discernible, on the front is a scroll with the figure 1. This number probably signifies that it was Newsham's number one model, the "cistern" of which had a capacity of 30 gallons, and was designed to discharge that volume of water to a distance of 26 yards in one minute of manual pumping. This machine, built in 1735, was used by Powers and Weightman for the protection of their chemical plant on Ninth Street, between Browne and Parrish Streets.

But this is not the earliest model in our possession. This distinction belongs to a smaller model on which is painted "Germantown 1764." The date is confusing, as this was one of the models acquired by the Common Council in 1730, and probably represents the smallest model for which 20 pounds was paid. The *American Weekly Mercury* of January 1734 informed its readers that "On Wednesday last was play'd at the Court-House a new Fire-Engine made in this city [Philadelphia] which threw the water much higher than the largest which this City had from London." It seems probable that with the acquisition of more efficient engines the city disposed of its less powerful ones, and that this model found its way to the Mutual Fire Insurance Company of Germantown, through whose courtesy it is exhibited here

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LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A.M. until 5 P.M.; Wednesdays and Thursdays from 2 P.M. until 10 P.M.

RECENT ADDITIONS

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THE FRANKLIN INSTITUTE

exists today because of the faith and generosity of the men and women who for 127 years have given time and money to its support.

The Institute welcomes financial gifts and bequests and hopes that all those who desire to perpetuate its work will make the The Institute one of their beneficiaries.

FORM OF BEQUEST

*I give and bequeath to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the sum of*_____

_____

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

***Abstract of* Alkaline Phosphatase Activity and pH Optima.**—M. H. Ross, J. O. Ely and J. G. Archer (*J. Biol. Chem.*, **192**, 561 (1951)). High pH values have been found necessary for optimum activity of alkaline phosphatase *in vitro*. The pH values in the living cell structures, on the other hand, are near neutrality: cytoplasm 6.9, nucleus 7.6. This definite difference between the pH required for optimum activity and the pH of the living cell indicates that alkaline phosphatase is not optimally active *in vivo*.

The optimum pH for alkaline phosphatase activity has been shown to be dependent upon the initial substrate concentration. At the optimum pH the rate of hydrolysis was found to be lower when the concentration of substrate was lower, but the small amount of phosphate released represented a greater proportion of available phosphate. A direct relation has been found between the pH optima and the substrate concentrations expressed logarithmically. At a concentration of 10 mg. per ml. of glycerophosphate, the optimum pH was 9.13, but at a concentration of 3γ per ml., the optimum pH was 7.35.

Since it has been shown that the pH optimum can be reduced from a non-physiological to a physiological pH, it is logical to assume that there is optimum alkaline phosphatase activity *in vivo*. It may be that other enzymes whose pH optima change with variation in substrate concentration, e.g. urease, also have as their pH optima *in vivo* the same pH as that of the cell.

BOOK REVIEWS

ADVANCED ENGINEERING MATHEMATICS, by C. R. Wylie, Jr. 640 pages, illustrations, 15 × 23 cm. New York, McGraw-Hill Book Co., Inc., 1951. Price, $7.50.

The author has skillfully presented the mathematics in a manner readily understandable by engineers. The book already is being used to teach graduate mathematics to engineers in several universities. Engineers find it a convenient reference book, for the material is self-explanatory.

The book assumes that the reader has a good background in the calculus. An extensive appendix is included, covering material from the borderline between calculus and advanced calculus, and the theory of equations. Several hundred problems have been completely worked out, and approximately a thousand problems, some containing hints and answers, have been graded in difficulty and posed for solutions.

The topics treated are as follows: Ordinary differential equations of the first order, linear differential equations with constant coefficients, simultaneous differential equations, mechanical and electrical circuits, Fourier series and integrals, the Laplace transformation, partial differential equations, Bessel functions, analytic functions of a complex variable, integration in the complex plane, infinite series in the complex plane, the theory of residues, conformal mapping, analytic functions and fluid mechanics, vector analysis, and numerical analysis.

The author draws many of his examples from such fields as thermodynamics, mechanical vibrations, strength of materials, fluid dynamics, electronic communication, power transmission, and aerodynamics. The great majority, however, are basic exercises of the manipulation under consideration.

In the opinion of the reviewer, *Advanced Engineering Mathematics* treats the essential mathematics used in mathematical engineering analyses. The material is well presented and illustrated with drawings; the specific examples demonstrate the usefulness of the techniques discussed and help review that study. The exercises foster dexterity in the technique.

A. D. HAY

HANDBOOK OF DANGEROUS MATERIALS, by N. Irving Sax, W. W. Schultz and M. J. O'Herin. 848 pages, diagrams and tables, 19 × 27 cm. New York, Reinhold Publishing Corp., 1951. Price, $15.00.

The practical value of this handbook is attested by the fact that the writing of the present review has been retarded as a result of continued demands for the book from laboratory personnel and a local committee on laboratory safety.

Information is arranged alphabetically under the general headings; General Chemicals (flammable, poisonous, corrosive, etc.) 410 pages; Explosives, 56 pages; Fungus Diseases and Fungicides, 64 pages; Radiation and Radiation Hazards, 70 pages; and Complete I.C.C. Shipping Regulations, 224 pages.

Individual items are discussed under several or all of the headings: Maximum Allowable Concentration in Air; Explosive Limits; Hazardous Properties; Treatment and Antidotes; Storage and Handling; and Shipping Regulations. Chemical formulas and physical and chemical properties, as well as a description of the appearance of the material, and also synonyms, are given in most cases. Additional items occur under "Fungus Diseases."

The complete coverage of the subject allows the devotion of an entire half page to the well-known and widely used substance, turpentine. Also included is the warning that exposure to furs and laundry soap as well as other common substances to which some persons are allergic should at times be avoided.

It is difficult to imagine a laboratory in which the book would not be useful. For laboratories of any size, it is a "must" if reasonable safety precautions are to be taken and occupa-

tional illness and accidents avoided. The book can be equally useful to the laboratory director and laboratory personnel, and will be understandable by the youngest technician.

A list of references, a tabulation of abbreviations and symbols, and an adequate index assist the reader of this volume, which in its completeness contains information on five thousand materials.

C. T. CHASE

MATERIALS TECHNOLOGY FOR ELECTRON TUBES, by Walter H. Kohl. 493 pages, drawings and photographs, 15 × 23 cm. New York, Reinhold Publishing Corp., 1951. Price, $10.00.

In the last decade the branch of electrical engineering which embraces the design of electron tubes has become a highly complex field in which many engineers have found full-time activity. The requirement for this extensive and specialized skill results from two things: the growing economic importance of the electronics industry, and the great variety of types of electron tubes required. A list of industrial applications or of different electron tube types would be lengthy if it included only the salient items. In view of the present importance of electron tubes in industry, the work of the author in bringing together the specialized information necessary for this engineering reference is certainly justified.

It should be realized that we are now dealing with electron tubes of many different forms, the 10-ft. long X-ray tube, the peanut-size subminiature, the large-screen television picture tube, the high-power magnetron and others. Therefore, it is necessary to treat the subject of electron tube materials in a rather fundamental way if the treatment is to be applicable to these very different forms of tubes. In considering the requirements of his text the author, Walter H. Kohl, has realized the necessity of assembling data from a number of separate technical fields. In reviewing the book it is convenient to fit most of the material into subject areas which include metallurgy, physics, electrical engineering, special laboratory practices and ceramics.

Much information on the use and properties of glass is given. Included in the treatment of this subject are chapters on the physics of glass, its heat treatment, strain analysis, electrical conduction in glass, electrolysis at elevated temperatures and the reaction of glasses to radiant energy. Since this information is of general engineering importance where glass is used, those concerned with the fabrication of scientific instruments and devices other than electron tubes may be interested in the book.

Typifying the author's treatment of physics is the discussion of space lattices and crystal systems as well as relationships like Gibb's Phase Rule which is useful in considering the final compositions of glasses and alloys. Under metallurgical considerations each significant metal —tungsten, molybdenum, tantalum, nickel, copper—is discussed in a separate chapter giving the physical properties and showing how they control its use in tubes. Important techniques are discussed in chapters on high-vacuum and the joining of glass and ceramics to metal.

There is perhaps no new information in this book, but it is unlikely that any engineer will read the volume without finding himself in unfamiliar territory part of the time. Those directly concerned with the design, fabrication and evaluation of electron tube construction in industry will be the primary users of this book. Likewise, the university student or research worker confronted with the necessity of constructing electron tubes or related apparatus will surely welcome the book's information on the use of glass and electrode components.

C. W. HARGENS

FUNDAMENTALS OF RADIO COMMUNICATIONS, by Abraham Sheingold. 431 pages, illustrations, 16 × 24 cm. New York, D. Van Nostrand Company, Inc., 1951. Price, $5.25.

On first leafing through the volume, one might derive the impression that this is "just another book on electronic fundamentals." Quite to the contrary! The author has incorporated into this volume a novel treatment of the subject, both from the standpoint of ready comprehension and the preservation of a keen interest in the material being presented. From the opening to the final chapter, the writer pursues a qualatative discussion in presenting the broad aspects of the field of radio communication.

This text is devoid of one of the limitations which is too often imposed on a book of this nature. The subject material is presented with a minimum use of higher mathematics thereby drawing attention to the end result rather than the method for obtaining the result. However, there has been sufficient use made of mathematical analysis to develop methods available for evaluating electronic circuits.

Throughout the book, there is a logical arrangement of topics and concepts that lead to an over-all understanding of the problems inherent in this particular field. *Fundamentals* is divided into four main sections each of which is comprised of several chapters.

Chapters One through Six are concerned with a review of the basic electric circuits, the components that comprise these circuits and the transfer of power that takes place in a given combination of components. In this section, the author dwells on the analysis of resonant circuits and resonant coupled circuits, and how the desired operation is secured by the selection of suitable elements and the application of appropriate voltages.

The next four chapters, Seven through Ten, are centered around the electron tube: its characteristics, associated circuits and application to circuits in general. Tubes are viewed from the standpoint of the mechanics of their operation; also, there is a quantative treatment of the effects of the circuit upon a tube to which it is coupled. Considerable detail is expended on the tube characteristic curves. Use is made of these current-voltage relationships in the tube to explain its operation as either a linear or nonlinear amplifying element.

Combinations of circuit elements, electric and tubes, into what are commonly referred to as electronic circuits are treated in chapters Eleven through Seventeen. Major circuits covered in this section come under the following headings: rectifiers, oscillators, amplitude and frequency modulation and pulse circuits.

The last section, Chapters Eighteen to Twenty-one, forms a general discussion of the problems of ultra high frequency techniques and their application to our everyday world. It was not the author's intention to go into much detail in this section, since it was intended to round out the subject of radio systems.

This first book in the Van Nostrand Series in Communications Engineering has well served the purpose for which it was evidently intended, that of giving a general coverage of the field of communications and preparing the novice for a more complete coverage of the subject in future texts.

T. J. BOWDEN

HEAVENS ON EARTH, by Mark Holloway. 240 pages, plates, 15 × 22 cm. New York, Library Publishers, 1951. Price, $4.75.

Few people who seek to understand communism think of turning to the records of those quixotic groups of people who have attempted to live under such social conditions on American soil. In fact, it will come as a surprise to many to learn that America has been the home of several experiments in this direction. Mr. Holloway offers in readable form a comprehensive guide to the origins, tribulations, and demise of these movements. Here the reader may survey the efforts of the Pietists, Shakers, Owenites, Rappites, Perfectionists, Fourierists, and several lesser groups who sought to establish a heaven on earth.

The book gives us an adequate picture of the ideologies, customs, dresses, and diets, but it neglects to deal with more practical aspects of communistic life. Even when the intelligence of the leaders was of a high order, as at Brooke Farm, intellectualism collapsed under its own weight for want of a pragmatic underpinning. It is not as though all these groups were composed of mystics, devoid of an interest in the technologies of progress. As the author informs us, the first communistically inspired group to settle in this country, the Pietists who settled in Germantown in 1694, brought with them telescopes. Their leader, Magister Johannes Kelpius, was a man of great learning who possessed apparatus for performing chemical and physical experiments. He does not appear to have done anything to advance science or to teach it. The Pietists, on the other hand, appear to have taken a more worldly view of the means of existence, for Kelpius lost his influence over them through the tardiness in the arrival of the millenium which he had confidently predicted.

The Shakers managed to survive rather longer, and this may have been because they were endowed with a practical energy. The author mentions their claims to have made their own circular saw (the first in this country), mower-and-reaper, planing machine, tongue-and-groove machine, revolving harrow, pea sheller, and metallic pen. Such a people were better fitted to accommodate themselves to an industrial economy. As their community began to dissolve they departed from strictly communistic principles (as the Oneida group had also done) but this failed to stem the drift toward dissolution.

The omission of information on economic relationships and technology leaves us in doubt whether the failure of the utopian groups to survive in the midst of progress was to be attributed to their inability to adjust themselves to a change in surrounding conditions or to the members becoming dissatisfied with theories. We should like to see someone with Mr. Holloway's qualifications undertake to study the economic aspects of American communism and tell us how the members of the groups overcame their technical problems. What we gather from this book is that the communistic societies must have been completely dependent for everything but their food upon the wider non-communistic nation which tolerantly offered them a refuge in which their ideas might be tested. But they must have lived by something more substantial than ideas, and that is what we should like to know about.

T. C.

ELEMENTS OF TELEVISION SYSTEMS, by George E. Anner. 804 pages, illustrations, plate, 15 × 22 cm. New York, Prentice-Hall, Inc., 1951. Price, $7.75.

For many years the rate of growth of the television art was much higher than that of the publication of information pertaining directly to the subject. Now Professor Anner has come forth with the subject volume which, for the time being, arrests the escape of the art. Here, in a "professional" book written at a graduate student or engineering level, are presented basic technical problems and their useful, practical solution.

The author recognizes three distinct types of television systems: closed, such as is used for industrial applications where the transmitter and receiver are connected by a wire link; commercial, where the receiver and transmitter are not physically connected; and color. Each of the three major sections of the book is devoted to one of these categories.

The book is remarkably complete in its presentation of the subject matter, using a broad engineering approach to the technical problems associated with television transmissions and reception. Such an approach also requires that system standards of performance be examined regardless of those which may have been standardized in commercial telecasting in the United States. This is the subject of an early chapter in the first part of the book where consideration is given to the choice of picture shape, system bandwidth, speed and direction of scan, and frame frequency. Scanning methods, scanning generators, and scanning and picture reproduction follow in succeeding chapters. Design equations for these component circuits are presented and several numerical examples are worked out.

Camera tubes which combine the functions of sampling, scanning and the conversion of light to some form of electrical signal are treated in a following chapter. Here primary interest is devoted to a flying spot device, the image dissector, the iconoscope, the orthicon and the image orthicon, which is the most flexible of the camera tubes insofar as variations in light intensity levels are concerned. Most camera tubes generate voltages which require broad band video amplification prior to further use. The analysis and design of such amplifiers, based upon steady state and transient requirements, are considered and numerous compensation procedures are introduced.

The first section of the book closes with three design problems of closed television systems, one of which in principle and detail approaches that of commercial telecasting methods and equipment.

The second part of the book is devoted to problems associated with standardization, vertical and horizontal resolution, synchronization between transmitter and receiver, vestigial side band transmission, transmitters, receivers, stagger-tuned amplifiers, receiving antennas, and the televising of motion pictures. As in the early part of the book, detailed design principles are stressed and are illustrated with circuits used in commercial equipment.

The third part of the book is devoted to color television, three main divisions of which are covered in elements of color, basic means of analyzing and synthesizing color in a television system, and details of practical color television system, including RCA simultaneous color, CBS sequential color, CTI line sequential color, RCA dot sequential, and the CTI segmented sequential system.

This volume fills a definite need among engineering textbooks for comprehensive and authoritative material on this subject. As presented, television can be looked upon as another phase of electrical engineering, much in the same way that the field of servomechanisms was viewed but ten years ago. The book is highly recommended to those engineers and students who desire a thorough groundwork in the subject.

S. CHARP

THEORY OF GROUPS AND ITS APPLICATION TO PHYSICAL PROBLEMS, by S. Bhagavantam and T. Venkatarayudu. Second edition, 227 pages, diagrams, 15 × 22 cm. Andhra University, Waltair, India, 1951. Price, Rs. 20.

Group theoretical methods have not received wide recognition as tools of mathematical physics in the past. There are two reasons which have made it difficult for less highly trained physicists to acquire facility in this subject: (1) Most of the texts were in German, and (2) Those texts which were available tended to stress the abstract mathematics rather than the physical applications of group theory. This book overcomes both of these difficulties and thereby becomes an admirable introduction to the topic from the physicist's point of view.

Applications are chosen largely from quantum physics. Here the group theoretical method divulges much information about the eigenfunction without laboriously solving Schrödinger's equation. Further applications are chosen from crystallography; here the authors derive some fundamentals, which are generally taken ad hoc, in a logical manner employing group theory. Classical vibrations, rotation operation, and vibrational spectra are also treated. The pure mathematics is minimized and only those theorems which have physical applications are discussed.

Group theory is first presented in a cursory manner. The intuitive ideas are demonstrated first with one and then two-dimensional lattices. Some crystallographic fundamentals of space groups are here exposed, lucidly illustrated with many diagrams. After laying the preliminary groundwork, the authors take a more formal approach to define carefully the concepts and expound important theorems. The Schrödinger equation is developed and the solutions to several examples are sought; emphasis is placed on the general properties of eigenvalue problems and the group form of linear operators.

There are further applications in the field of molecular spectra, the fundamentsls being first derived for classical oscillators. Vibrations in crystals, space lattices, crystal classes, space groups, some classical groups such as rotations in two or three dimensions and Lorentz groups are also systematically treated. Numerous other specialized illustrations of group theory's applications are included.

Those aspects of the discussion which the more mathematically inclined reader may follow in the appendices include: fundamentals of group algebra, transformation of matrices, Kramer-Heuenberg dispersion formula, evaluation of group characters, properties of some polynomial functions, Laplacian operators, and the reduction of reducible representations.

JAMES A. WEINMAN

HIGH FREQUENCY TRANSMISSION LINES, by Willis Jackson. 152 pages, illustrations, 11 × 17 cm. London, Methuen & Co., 1951; distributed in U. S. by John Wiley. Price, $1.75.

High Frequency Transmission Lines is another of Methuen's Monographs on Physical Subjects. Transmission lines for power transmission and telephonic communication are studied by all electrical engineering students at a comparatively early stage. This volume is by no means a textbook for such students; it should appeal more to an engineer who is thoroughly acquainted with the subject and who wants to obtain a quick review of the subject matter in an easily readable form.

Contrary to procedures followed in many books, the author develops the equations for a transmission line from Maxwell's equations; these are then specialized for the cases of coaxial and twin lead lines. Emphasis throughout the book is on high frequency applications, where the line can serve as an interconnector and/or as a circuit element. Following a chapter devoted to applications at very high frequencies, there are developed the equations for propagation in the principal mode. The characteristics of transmission lines are next considered, with special problems pertaining to: conductor and dielectric assemblies; skin effect; line parameters; effects of small changes in dimensions; and temperature rise in solid dielectric lines. Chapters on terminated lines, resonant lines, and impedance transformations close the book.

Engineers who are concerned with experimental applications of transmission lines at high frequencies will find much of interest in this short work.

S. CHARP

BOOK NOTES

CORROSION GUIDE, by Erich Rabald. 629 pages, illustrations and tables, 16 × 25 cm. Houston, Elsevier Press, 1951. Price, $12.50.

The author has compiled this book to aid in solving the corrosion problems of chemical manufacture and has addressed it to chemists and engineers who are translating a laboratory preparation to an engineering scale. The information is presented in tabular form, with 550 of the book's 629 pages containing corrosion tables. The descriptive part of the book contains chapters on the principles of corrosion and the measurement of corrosion resistance. The resistance of some forty materials of construction to over 250 media is shown. The information given is very condensed, but very usable.

FUNDAMENTALS OF SEMIMICRO QUALITATIVE ANALYSIS, by Erwin B. Kelsey and Harold G. Dietrich. Revised edition, 328 pages, diagrams and tables, 15 × 22 cm. New York, The Macmillan Co., 1951. Price, $4.00.

The text represents a complete rewriting and simplification of the original text. The scope is not changed—fundamental theory is covered under headings of nature of substances, solutions, ionization, protolytic equilibria, precipitates, and principles of oxidation-reduction. Analytical procedures are under systematic cation analysis, analysis for non-metal ions, and analysis of solids (non-metallic and alloys).

REFERENCE BOOK OF INORGANIC CHEMISTRY, by Wendell M. Latimer and Joel H. Hildebrand. Third edition, 625 pages, diagrams, 14 × 22 cm. New York, The Macmillan Co., 1951. Price, $5.00.

The third edition is a bringing up to date of a text to be used as reference in inorganic chemistry. The form of the book has not been changed, but it contains much new material. Actinum and the heavier elements are treated in a new chapter. The chemistry of plutonium and the other new transuranium elements receive considerable attention in this chapter, as do nuclear fission and various pile reactors. Additions have been made to most chapters. Oxidation-reduction potential diagrams are given for almost every element and increased emphasis has been placed upon thermodynamical data.

COLLEGE ZOOLOGY, by Robert W. Hegner and Karl A. Stiles. Sixth edition, 911 pages, diagrams and illustrations, 16 × 24 cm. New York, The Macmillan Co., 1951. Price, $6.00.

The material in this, the sixth edition, textbook has been revised, many chapters rewritten, new illustrations used, new sections added on Rh factor, enzymes, vitamins, radioactive substances, and other subjects. The cat is the representative mammal. It is an interesting presentation of introductory material for the student of zoology.

CURRENT TOPICS

Radio System for Detecting Enemy Planes and Guided Missiles.—Brigadier General David Sarnoff, Chairman of the Board of the Radio Corporation of America, has been granted U. S. Patent No. 2571386, for an automatic early warning system which combines the principles of television, radar, microwave relay, and the latest methods of detection and direction-finding. The new system can utilize equipment already developed and in use.

In describing the principles of the system disclosed in this patent, Dr. Elmer W. Engstrom, Vice President in Charge of RCA Laboratories Division with headquarters at the David Sarnoff Research Center, Princeton, N. J., said:

"General Sarnoff's patent discloses a method and means for surveillance of a string of areas off-shore, or remote from the borders of a country, for detection of planes, guided missiles, enemy vessels, or other targets in those areas. It provides for instantaneous communication of running target positions to a central intelligence station or command post within the country.

"The patent describes a method and means for dispatching fighter aircraft and directing them to the enemy planes, guided missiles, or the like that have been detected.

"It also describes means for early interception of report and control signals sent from and to a guided missile, and the radiating of identical signals for jamming of the channel, or counter-controlling of the missile.

"The system proposed by General Sarnoff would enable detection at much greater distances than is now feasible. At the same time it would transmit the information to a Control Center that could act immediately. By this new method, countermeasures will have a greater opportunity to deal with enemy planes or guided missiles that might be carrying atomic bombs and to destroy them at sea before they can reach their targets on land.

"A further object of this invention is to provide an improved radar fence with a greater depth of protected area.

"The patent specification includes information about an airborne radar net for national defense in which a succession of planes leaving shore on a predetermined course, search the specified area with radar equipment. The information thus compiled, is then relayed automatically from the lead plane successively through the trailing planes and finally to the Control Center on the home base. In this way, the radar net is moved continuously across vast distances covering possible enemy invasion routes.

"By adding a television camera to the plane's equipment, as explained in the patent specification, the radar information, together with dial readings indicating airspeed, compass bearing, altitude of the craft and any other needed facts, can be relayed to the Control Center in the form of a continuously changing television picture.

"General Sarnoff's patent also describes means for intercepting the control and position signals transmitted by an enemy to and from a guided missile and the immediate radiation of identical signals for the purpose of eliminating

enemy control over the winged weapon. In this way, the missile could be directed on a new path which would be continued until its fuel is exhausted and it falls harmlessly into the sea or on an uninhabited land area.

"In a variation of the same military application, the patent specification describes an arrangement for the early detection of enemy planes or long-range radio-controlled missiles, and describes a method for dispatching fighter aircraft to meet and destroy them long before they are able to reach their objective.

"This could be accomplished by launching parasitic planes from the aircraft or radar patrol. These parasite planes, equipped with radar and radio would send back to the nearest group of defensive fighter planes a continuous flow of signals giving the position, speed and direction of flight of the enemy plane or missile. Supplied with this information, the fighter planes, taking off from land base or carrier, would be able to set their course accurately to intercept their target.

"As a peacetime service, the disclosed system would apply also to a similar chain of spaced planes extending from shore to shore which could be utilized to relay television programs to and from Europe and other foreign countries. Such a relay system, according to the patent specification could also carry high speed ultrafax communications.

"Because of the proposed use of lightweight, low-power microwave relay apparatus, General Sarnoff's plan could be adopted for both military and non-military purposes without materially affecting the freight and passenger carrying capacity of the planes."

Nitric Acid from Air.—Chemical wizardry is pulling a basic ingredient of explosives and fertilizers right out of thin air. Scientists now are converting the nitrogen of the air into nitric acid, vitally needed in the manufacture of many explosives and propellents, the key to valuable fertilizers, and potentially of great importance to industry. Pilot plant operation is now producing a ton of 60 per cent nitric acid a day, and plans are underway for full scale production.

They are making the conversion through the Wisconsin process, so named because the basic research was done at the University of Wisconsin by Prof. Farrington Daniels and several of his co-workers from a theory originally advanced by Dr. F. G. Cottrell, formerly of the University of California.

Dr. Daniels and his associates took on the problem of milking the air of its nitrogen in 1939. As the U.W. chemist saw it, two problems were involved —the production of nitrogen oxides from the air, and the recovery of the minute amounts of nitrogen oxides, once they had been formed.

To solve the first problem, Dr. Daniels and a graduate student, Nathan Gilbert, built a gas-heated furnace which contained two separate beds of magnesium oxide pebbles, excellent for absorbing and holding heat. Pioneer work by Cottrell and Percy H. Royster has developed this type of furnace for efficient heating and cooling of gases.

The furnace resembled a square horseshoe, open end down. At the bottom of each side was a magnesium oxide pebble bed, each connected to a single air vent. A valve at the junction of this connection enabled the operator to direct air to either of the pebble beds separately.

Air was blown into one of the pebble beds, preheated there to make possible

higher temperatures, and forced around the top of the "horseshoe" to come in contact with burning fuel gas. This gas, burning in the preheated air, gave a temperature of about 4000 degrees Fahrenheit, or several hundred degrees higher than would be possible without preheating. At 4000 degrees, about two per cent of the air was converted into nitric oxide.

This mixture continued around the "horseshoe," down through the other pebble bed. There the magnesium oxide pebbles absorbed the heat so quickly that the nitric oxide was "frozen" before it had time to revert back to nitrogen and oxygen.

When the pebble bed that was absorbing the heat reached a certain temperature, the operator could turn the valve and redirect the outside air through that bed. Because of the tremendous heat, the air was preheated to higher temperatures, and nitric oxide was formed in increased concentration when the burning occurred at the top of the "horseshoe." The first heating bed then became the cooling bed.

"The valve is turned when the exit gases reach a predetermined temperature," Dr. Daniels explains. "The cycles become shorter as the furnace heats up, and eventually reach a steady operating time."

Gilbert left in 1942 and another graduate student, W. G. Hendrickson, joined Dr. Daniels. The men built a preliminary pilot plant and by 1944 were obtaining good yields of nitrogen oxides. But there was a hitch—the furnace materials kept breaking down, preventing sustained production.

Seeking a better building material became a major technical problem as industry joined in the battle to prevent furnace breakdown. Finally, after eight years, the scientists came up with a purer version of magnesium oxide that filled the bill perfectly—in fact, got stronger with use.

At the same time this research had been going on, studies to recover the nitrogen dioxide also were under way by Dr. Daniels and another of his talented graduate students, E. Gordon Foster. Their research has led to a recovery system which converts the two per cent nitric oxide from the furnace into concentrated nitrogen dioxide. The nitrogen dioxide then can be converted into nitric acid in small water towers.

The Wisconsin process, unlike other methods, requires only air, water, and energy for raw materials; its equipment is simple and it is possible to operate with smaller units than with other methods of nitrogen fixation, the scientists say.

Through University-industry cooperation, the way has been opened for comparatively inexpensive nitric acid and all the uses to which it can be put.

Underwater television cameras developed by the Navy's Bureau of Ships will safeguard human life and facilitate salvage and other underwater operations, as well as save valuable time. In depths of over 200 feet, a diver spends greater part of a dive in the descent and ascent, with added drawback that walking on the bottom may stir up silt and block his own view, while a TV camera may be quickly lowered and raised; with suspended lights, personnel on board ship may make lengthy observations of the ocean bottom, even filming the televised picture for future reference if necessary. Salvage operations in future may be completely planned before a diver ever goes down to do the actual work.

Certified Protection Against Lightning.—Recently, at the White House, newly installed lightning rod equipment was certified by attachment to the building of a Master Label of Underwriters' Laboratories, Inc.

Before attaching the label, Messrs. W. J. Alcock and C. G. Smith of Underwriters' Laboratories, Inc. in Chicago, were all over the White House checking the following: Bonding of metal objects to the lightning rod system, such as ventilators, television antenna and particularly the tall flag pole; spacing of air terminals; proper coursing of roof conductors; grounding of the system to the water pipe and checking the continuity of the entire system as well as the resistance to ground. These two men started at the top measuring the resistance at the air terminals and continued down to the ground, measuring the resistance between the down conductors and grounding rod.

Underwriters' Laboratories, Inc., sponsored by the National Board of Fire Underwriters, inaugurated the Master Label program early in 1923 and during the first year of operation Master Labels were issued for the installation of 4786 structures. Since 1923, there have been over 150,000 Master Labels issued and far less than one per cent have been reported as being damaged by lightning during this 29-year period.

Insurance rating organizations recognize the protection afforded by lightning rods to the extent that, in 20 states, credits of from 2 per cent to 10 per cent are given in fire insurance policies covering buildings with Master Label lightning protection systems.

The above installation is not the first one in Washington. Shortly after being built, the 550-ft. Washington Monument was found not to be immune from lightning damage. This shaft was damaged by lightning several times prior to 1885, but after a system of lightning protection was provided, no further injuries were suffered, although lightning has struck many times. Among the monuments equipped with lightning protection are the Statue of Liberty in the New York Harbor, the Bunker Hill Monument at Boston, Indiana's World War Memorial at Indianapolis, the Admiral Perry Monument at Put-In-Bay, Ohio, and many others.

One-Minute Photomicrographs.—E. Leitz, Inc., now offers a photomicrographic device which makes it possible to use the Polaroid Land Camera as a one-shot photomicrographic camera. The finished print is available within one minute after the exposure is made, and prints may be used for temporary or permanent records or as a guide in determining exposure for more universal photomicrographic setups. While this one-shot camera arrangement is not expected to replace the standard photomicrographic camera, its speed and simplicity should prove valuable both to laboratories with elaborate photographic equipment as well as small laboratories which do not possess such equipment.

Working in conjunction with the offices of the Polaroid Corporation in Cambridge, Massachusetts, Leitz developed a combination of the Land camera with the Leitz photomicrographic apparatus MA-IVb. A standard microscope with monocular tube is used, and it is provided with a split beam telescope that clamps into position over the eyepiece. The split beam prism housing has a built-in shutter with variable speeds up to 1/125th second.

The film supplied by the Polaroid Corporation for photomicrographs is orthochromatic, but panchromatic film also will be available soon.

BY-LAWS

ARTICLE I

Stock

Section 1. The Real and Personal Estates of the Institute as held upon the First day of January, One Thousand Eight Hundred and Eighty-one, shall be valued at One Hundred Thousand Dollars, and shall be represented by Ten Thousand Shares of Stock of the par value of Ten Dollars each. Said shares shall be divided into two classes, *viz.:*

First Class. Shares not registered for use: on which no annual payment shall be charged or collected, and the holders thereof shall not have the privileges of members of the Institute, but may, if of legal age, vote at any annual election for managers upon the payment of One Dollar upon each share of stock on which they may desire to vote; provided, however, such shares have been held by the same person at least three months before such election.

Shares of the First Class may be converted into shares of the Second Class at the pleasure of the owners, provided the transfer be approved by the Board of Managers; but, when once so converted, they shall always continue in the Second Class.

Second Class. Shares registered for use: on which Twelve Dollars per annum shall be due and payable from resident members in advance on the first day of October in each year, except as hereinafter provided.

Non-resident holders of Second Class stock shall pay an annual fee of Five Dollars.

Section 2. The holders of Second Class stock shall be entitled to the use of the library, lectures and reading-room, and if of legal age, to all other privileges of membership in the Institute, so long as they make the annual payment in advance; and shall, on the payment of One Dollar therefore, be entitled to a Certificate of Membership.

Section 3. If the annual dues for successive years remain unpaid at the expiration of two and a half years on any share of stock of the Second Class, such shares shall then become forfeited to the Institute; but such forfeiture may be remitted by a unanimous vote of the Board of Managers.

Section 4. Stock of the Second Class may be held in trust for persons not of legal age, and shall be liable to the payment of only one-half the annual fees due upon stock of Second Class held by persons of legal age; provided, that when such minors arrive at legal age, new certificates, subject to the full annual contribution, shall issue on payment of the customary fee.

Section 5. Certificates for the First Class stock may be issued for any number of shares in a single certificate; but every certificate for the Second Class shall be for one share only.

Section 6. No share of stock in the Second Class shall be transferred until all arrearages and fines are paid, and all books and tickets returned, and the transfer approved by the Board of Managers.

Section 7. All certificates of stock shall be signed by the President and Secretary; shall be issued by the Controller, and shall be transferable only on the books of the Institute by the owner, or his legal representative, on the surrender of the old certificate, and of a fee of twenty-five cents for each certificate.

Section 8. All subscriptions to stock shall be approved by the Board of Managers before the certificate can be issued.

ARTICLE II

Members

Section 1. All persons interested in the purposes and activities of the Institute and willing to further them may become members when elected by the Board of Managers, or in a manner prescribed by the Board, except as qualified by Section 6 of this Article. Membership shall consist of the following classes:

1. Student members
2. Associate members
3. Active members
4. Sustaining members
5. Honorary members

The Board of Managers may establish other classes of members, provided that the privileges enjoyed and dues paid by such other classes are not inconsistent with the privileges and dues of the classes of members specifically provided for by these By-Laws.

Section 2. Student members shall be under twenty-five years of age and shall pay annual dues of $2.00. They shall be entitled to unlimited free admission to the Museum and the Planetarium. Student members who are fourteen or more years of age may, if endorsed by a teacher or an Active member, have the use of the library upon the payment of additional annual dues of $1.00 but shall have no voting privileges or rights to hold office.

Section 3. Associate members shall pay annual dues of $5.00. They shall be entitled to unlimited free admission to the Museum and to the Planetarium, but shall have no voting privileges or rights to hold office. Upon the payment of $5.00 additional annual dues they shall have Family privileges as defined in Section 7 of this ARTICLE.

Section 4. Active members shall be not less than twenty years of age. They shall pay annual dues of $15.00. Active members, residing permanently at a distance of fifty miles or more from Philadelphia, shall pay annual dues of $7.50. Active members shall be entitled to use the library, to receive one copy of the Journal of The Franklin Institute, to vote and to hold office. They shall be entitled to all the privileges of Associate members and upon the payment of $5.00 additional annual dues shall be entitled to Family privileges.

Section 5. Sustaining members shall be not less than twenty years of age. They shall pay annual dues of not less than $50.00. They shall be entitled to all of the privileges of Active members and shall have Family privileges as defined in Section 7 of this ARTICLE free of additional charge.

Section 6. Honorary members shall be entitled to all of the privileges of sustaining members, except the right to vote and to hold office. They shall be nominated by the Board of Managers and shall be elected by four-fifths of the votes of the members present at any stated meeting of the Institute at which their nomination may be acted upon.

Section 7. Family privileges consist of the right to receive a card for each individual in the family of the member and resident with the member entitling the holder to unlimited free admission to the Museum and the Planetarium.

Section 8. Members belonging to classes of membership existing prior to the amendment of this ARTICLE shall be reclassified in a manner consistent with their former dues and privileges.

ARTICLE III

PAYMENT OF DUES

Section 1. The annual fees for membership shall be due and payable on the first day of each month, whichever is nearest to the date of election or as determined by the Board of Managers.

Section 2. Any member whose dues are more than two months in arrears shall have all the privileges of membership suspended until such time as all arrears are paid. Should the dues not be paid when they become six months in arrears the said member shall forfeit his membership.

Section 3. The Board may remit temporarily in whole or in part the dues of any member either by action in a particular case or by establishing regulations governing certain cases.

Section 4. Every person admitted to membership in the Institute shall be considered as liable for the payment of dues until he shall have resigned, been dropped or have been relieved therefrom by the Board of Managers.

Section 5. Resignations of memberships shall be made to the Board of Managers in writing, but need not be accepted until all dues and arrears up to date of resignation shall have been paid.

Section 6. The privileges and title of Associate member may be obtained for life by paying therefor in one year the sum of $100. From this payment may be deducted one-half of the Student or Associate Membership dues paid by the member during the preceding ten years, but in no case shall the deduction exceed $50.00.

Section 7. The privileges and title of Active Member shall be enjoyed for life or may be obtained for life by a member who has heretofore or who shall hereafter pay therefor, in one year, the sum of $300, except

that a person residing permanently at a distance of twenty-five miles or more from Philadelphia may become an Active Member for life by paying therefor in one year the sum of $100. From this payment may be deducted one-half of the dues paid by the member during the preceding ten years, but in no case shall the deduction exceed one-half of said payment. Associate Members for life may become Active Members for life by paying therefor in one year the sum of $200.

Section 8. Firms, corporations, associations or individuals may nominate and subscribe for the membership dues of groups of members of any class or classes, at the annual dues provided for, subject to the approval of the Board as to any particular nominee. If the dues of these nominees amount to $100 or more in the aggregate, the firm, corporation, association or individual shall be known as an Affiliate of the Institute.

ARTICLE IV

MANAGEMENT

Section 1. The Institute shall be governed by a board of twenty-four (24) Managers elected by the members.

Section 2. The officers, who shall be elected by the Board of Managers, shall be a President, an Executive Vice President, not more than five Vice Presidents, a Secretary, an Assistant Secretary, a Treasurer, and an Assistant Treasurer. The Board of Managers may elect such other officers as it deems necessary.

Section 3. At the annual meeting of the Institute, eight Managers shall be elected each year to serve for three years, provided that the Managers now elected, or who may hereafter be elected, shall continue to serve until their successors be appointed.

Section 4. All elections of the Institute shall be by letter ballot and no vote may be cast by proxy.

Section 5. Nominations for Managers shall be made in writing at the stated meeting in the month of December. Each nomination paper must be signed by at least two members, who shall certify that the candidate will serve if elected. After the nominations are closed, the President shall appoint three members, who are neither officers nor nominees, to act as tellers of election. The list of nominees shall be posted at the Institute and incorporated (with directions for voting) in a ballot to be sent to each member by the Secretary at least one week before the date of election. Each ballot shall be accompanied by a return envelope addressed "To the Tellers of Election," and provided with a space for the signature of the member voting.

Section 6. On the date of the annual meeting, and at an hour previously designated by their chairman, the tellers shall meet at the Institute, and shall count all legal votes that have been received by mail or placed in the ballot box before eight o'clock P.M.; and when the count is completed they shall report to the annual meeting of the Institute the total number of ballots cast, together with the number of votes received by each candidate. Thereupon the presiding officer shall announce the names of the candidates who received the plurality of votes, and shall declare them elected Managers of the Institute for the ensuing terms.

Section 7. At the organization meeting of the Board of Managers, the Board of Managers shall elect the officers provided for in Section 2 of ARTICLE IV to serve for one year; and may at said organization meeting or from time to time thereafter elect such other officers as it may determine upon, and shall determine and fix the compensation, if any, to be paid to the officers so elected or appointed by them. The officers who are in office immediately prior to the annual meeting shall continue in office until their successors are elected or appointed by the Board of Managers as herein provided.

Section 8. Vacancies occurring in any office may be filled by the Board of Managers by election or appointment of persons to serve until the next annual election.

ARTICLE V

BOARD OF MANAGERS

Section 1. The Board of Managers shall have general charge and control of the Institute and of the Benjamin Franklin Memorial and The Franklin Institute Museum, and shall consist of twenty-four members elected as provided in ARTICLE IV. The President, the Executive Vice President, the Vice Presidents, the Secretary, the Treasurer, the Chairman of the Committee on Science

and the Arts, and the Chairman of the Library Committee shall be *ex officio* members. A quorum of the Board of Managers shall be nine of the elected and *ex officio* members. The Board of Managers may adopt such by-laws, rules and regulations for the governance of their affairs as are not inconsistent with the Charter and these By-Laws.

Section 2. They shall present, through the President, at the annual meeting of the Institute, a report of the condition of the affairs of the Institute.

Section 3. They shall hold stated meetings in each month except in July and August.

Section 4. Special meetings may be called by the President at his discretion and shall be called by him on written request of the Executive Committee or of any seven members of the Board. In case of his absence or refusal to act, such special meeting shall be called by the Secretary.

Section 5. Members who have not attended five regular meetings in the twelve months prior to the stated meeting of the Institute in December, shall be reported thereat as having resigned, unless it be unanimously voted by the Board at that meeting that such member has been absent for sufficient reason.

Section 6. All vacancies on the Board of Managers shall be filled by the Board until the next annual meeting of the Institute.

Section 7. The Board of Managers may elect an Executive Committee consisting of five of its Members with such authority to act on behalf of the Board as the Board may delegate.

ARTICLE VI

DUTIES OF OFFICERS

Section 1. The President shall be the executive head of the Institute and, under the supervision of the Board of Managers, shall have general charge of the affairs of the Institute. He shall preside at all meetings of the Institute and of the Board of Managers and shall be, *ex officio*, a member of all standing committees of the Institute.

Section 2. The Executive Vice President, under the supervision of the President, shall have immediate charge of all affairs of the Institute other than those matters specifically delegated by action of the Board of Managers pursuant to these By-Laws to the Executive Committee and the Finance Committee. He shall prepare the annual budget, and submit it to the Board of Managers for approval. He shall be an *ex officio* member of all standing Committees of the Institute. He shall report to the President. In case of the disability of the Executive Vice President, the President shall designate another officer or other officers to assume his duties.

Section 3. In the absence of the President, the Executive Vice President shall exercise his duties. In the absence of both the President and the Executive Vice President, the Vice Presidents shall exercise the duties of President in order of their seniority in office.

Section 4. The Secretary shall be responsible for keeping the minutes of all meetings of the Institute and of the Board of Managers, shall keep the records of the Institute, and shall perform all the duties usually pertaining to the office of Secretary. He shall report to the Executive Vice President. In the absence or disability of the Secretary, the Assistant Secretary shall perform his duties.

Section 5. The Treasurer shall have custody of all monies received from the Committee on Finance together with all monies received by the Institute from dues, admissions, and other operations of the Institute, depositing them, in the name of the Institute, in such bank or banks as the Board of Managers shall direct and disbursing them by checks signed as the Board of Managers shall likewise direct. He shall keep accounts of the receipts and disbursements and shall report thereon to the Board of Managers as directed. He shall have general supervision of the accounts of the Institute and shall render such financial statements as directed by the Board of Managers. He shall give bond to an amount and with such surety as the Board of Managers shall determine. The Treasurer shall report to the Executive Vice President. In the absence of the Treasurer, the Assistant Treasurers shall, in the order of their seniority in office, perform his duties.

ARTICLE VII

BOARD OF COUNCILLORS

The Board of Councillors shall consist of not more than fifty members and shall embrace, as *ex officio* members, the Governor of

Pennsylvania, the Chief Justice of the Supreme Court of Pennsylvania, the Mayor of the City of Philadelphia, the President of the City Council of Philadelphia, the President of the Board of Public Education and the Superintendent of Schools of the City of Philadelphia, the Provost and the President of the University of Pennsylvania, the President of Commissioners of Fairmount Park, the President of the American Philosophical Society, the President of the Poor Richard Club, and the President and Secretary of The Franklin Institute, which two latter shall respectively be Chairman and Secretary of the Board of Councillors. Additional members shall be nominated by the President or Secretary of the Institute and elected by the Board of Managers, at such intervals as the Board of Managers may see fit. The Board of Councillors shall meet at the call of its Chairman or of the Board of Managers for the consideration of any matter that pertains to the welfare of the Institute. The Secretary shall from time to time send to the members of the Board of Councillors a report of the activities and accomplishments of the Institute.

ARTICLE VIII

COMMITTEES OF THE INSTITUTE

Section 1. There shall be the following Standing Committees of the Institute:

1. Bartol Research Foundation Committee.
2. Biochemical Research Foundation Committee.
3. Committee on Science and the Arts.
4. Endowment Committee.
5. Finance Committee.
6. Library Committee.
7. Meetings Committee.
8. Membership Committee.
9. Museum and Memorial Committee.
10. Publications Committee.
11. Committee on Research.

Section 2. Each standing committee of the Institute shall consist of the number of members determined on by the Board of Managers and composed of members of the Board of Managers and/or non-members as may be desirable, except that the Committee on Science and the Arts shall consist of not less than sixty nor more than seventy-five members, and except that the Bartol Research Foundation shall consist of not less than ten nor more than fifteen members as provided for in Section 7 of this ARTICLE.

Section 3. The members of each committee shall serve one year, except that members of the Committee on Science and the Arts shall serve three years.

Section 4. The members of each committee, other than *ex officio* members specifically provided for by these By-Laws, shall be appointed by the President and approved by the Board of Managers at the organization meeting of the Board following the annual meeting except that each year but one-third of the total number of members of the Committee on Science and the Arts shall be so appointed and approved.

Section 5. The Chairman of each Committee shall be designated by the President, except that the Library Committee and the Committee on Science and the Arts shall select their chairmen. A chairman who is not an elected or *ex officio* member of the Board of Managers shall have the privilege of the floor at meetings of the Board but shall not have the right to vote.

Section 6. Each Committee shall report monthly to the Board of Managers through its Chairman. A copy of their report shall be in the hands of the Executive Vice President one week before the monthly meeting of the Board.

Section 7. The Bartol Research Foundation Committee shall consist of not less than ten nor more than fifteen members, including the President and the Executive Vice President of the Institute and the Director of the Bartol Research Foundation as *ex officio* members and nine members of the Institute of whom not more than four shall be members of the Board of Managers. The Committee shall, after consultation with the Director of the Bartol Research Foundation and subject to the approval of the Board of Managers, collaborate with the Executive Vice President in carrying out the purposes and determining the policies of the Bartol Research Foundation. It shall appoint the Director and the Staff of the Laboratories, subject to the approval of the Board of Managers. The Director of the Bartol Research Foundation, to whom all other employees of the Founda-

tion shall report, shall have charge of the scientific activities of the Foundation and shall report on all matters to the Committee or to the Executive Vice President, as the Committee may elect.

Section 8. The Biochemical Research Foundation Committee shall report to the Board of Managers from time to time on the condition of the affairs and operation of said Foundation and shall be available to the Director of the Biochemical Research Foundation and its Advisory Council for collaboration and advice.

Section 9. The Committee on Science and the Arts shall investigate current discoveries, inventions and other achievements in the sciences and their application in the mechanical and industrial arts with a view of affording such recognition as may lie within the power of the Institute to bestow. The Committee shall exercise independent judgment therein. In all matters of a general or administrative nature the Committee shall collaborate with the Executive Vice President.

Section 10. The Endowment Committee shall, in collaboration with the Executive Vice President, encourage the gift of funds to the Institute.

Section 11. The Finance Committee shall have the custody and control of all the securities and investments of the Institute with full power and authority to buy and to sell, and to invest and reinvest the same; including the power to satisfy mortgages and extinguish ground rents, and to direct the placing of all such insurances on Real Estate held for investment as it may deem necessary, and to make such improvements, repairs and alterations to such Real Estate as it may deem necessary. It shall have power to authorize the proper officers of the Institute to execute the necessary papers to effect all purchases, sales and assignments of property other than real estate; to transfer registered securities; to subscribe to bond-holders' agreements to plans of reorganization involving any securities held by the Institute or in which it has an interest; and to do all such acts as are necessary in pursuance of the foregoing powers. It may, with the approval of the Board of Managers, appoint a Trust Company of the City of Philadelphia to act as Fiscal Agent under the direction of the Committee.

The Finance Committee shall keep a record of all its acts and proceedings, which shall be communicated to the Board of Managers.

Section 12. The Library Committee, in collaboration with the Executive Vice President, shall be of counsel and advice in the purchase of books and publications suitable to and consonant with the purposes of the Library; and in other matters pertaining to the Library.

Section 13. The Meetings Committee shall, in collaboration with the Executive Vice President, secure for presentation before the Institute papers dealing authoritatively with subjects of import in the fields of science, engineering and industry.

Section 14. The Membership Committee shall, in collaboration with the Executive Vice President, promote the several memberships defined in ARTICLE II of these By-Laws.

Section 15. The Museum and Memorial Committee shall, in collaboration with the Executive Vice President, be of counsel and advice to the Director of the Benjamin Franklin Memorial and The Franklin Institute Museum, and with the scientific staff of the Museum concerning the activities and the exhibits of both the Museum and the Memorial.

Section 16. The Publications Committee, in collaboration with the Executive Vice President, shall be of counsel and advice with regard to all publications of the Institute other than publications of the Bartol Research Foundation.

Section 17. The Committee on Research shall, in collaboration with the Executive Vice President, be of counsel and advice to all research activities of the Institute except those of the Bartol and Biochemical Foundations.

Section 18. Each committee shall organize and adopt rules as it sees fit, subject to the provisions of these By-Laws and the approval of the Board of Managers.

ARTICLE IX

MEETINGS

Section 1. The Institute shall hold stated meetings on the third Wednesday of each month, except in June, July, August and September, at 8:15 P.M.

Section 2. Special meetings shall be called by the President upon the order of the Board

of Managers or within ten days upon the written application of twenty-four voting members of the Institute.

Section 3. Twenty-four members shall constitute a quorum at any stated or special meeting.

Section 4. The Annual Meeting of the Institute shall be held on the third Wednesday of January of each year at 8:15 P.M. Elections at Annual Meetings shall not result from the poll of less than forty-eight ballots cast in accordance with ARTICLE VI, Section 6, of these By-Laws.

ARTICLE X

AMENDMENTS

These By-Laws may be altered or amended at any stated meeting of the members of the Institute, provided notice in writing, signed by two members, of the proposed alteration or amendment, shall be given to the Board of Managers two months prior to the said meeting, except that amendments to ARTICLE I, relating to capital stock, must be ratified subsequently by a majority of the stock represented at a meeting specially called for this purpose.

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Free admission to the Museum, Planetarium, and Institute Lectures is granted to all members and to the families of Sustaining, Active Family, and Associate Family members.

The Institute News, which includes news items about the Institute as well as announcements of meetings and lectures, is sent to all members.

The *Journal of The Franklin Institute* is sent to Sustaining, Active Life, Active Family, and Active members.

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The Elliott Cresson Medal (1848—Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (1906—Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The John Price Wetherill Medal (1925—Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (1890—Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (1923—Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The George R. Henderson Medal (1924—Gold Medal).—This medal is awarded for meritorious inventions or discoveries in the field of Railway Engineering.

The Walton Clark Medal (1926—Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Frank P. Brown Medal (1938—Silver Medal).—This medal is awarded to inventors for discoveries and inventions involving meritorious improvements in the building and allied industries.

The Newcomen Medal (1943—Gold Medal).—This medal is awarded, not oftener than once in three years, for achievement in the field of Steam.

The Francis J. Clamer Medal (1943—Silver Medal).—This medal is awarded at least once in five years for meritorious achievement in the field of Metallurgy.

The Stuart Ballantine Medal (1946—Gold Medal).—This medal is to be awarded in recognition of outstanding achievement in the fields of Communication and Reconnaissance which employ electromagnetic radiation.

The Boyden Premium (1859).—This premium is awarded not oftener than once in five years to any resident of North America who has recently made a notable experimental determination of the speed, in free space, of radiation in any region of the entire spectrum.

The William M. Vermilye Medal (1937—Bronze Medal).—This medal is awarded not oftener than biennially in recognition of outstanding contribution in the field of Industrial Management.

The Certificate of Merit (1882).—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

For further information relating to these awards apply to The Executive Director.

(Revised to August, 1951.)

What's inside a *Radio-Relay* station?

Because microwaves travel in straight lines and the earth is round, there are 123 stations on the transcontinental television route between Boston and Los Angeles. This view of a typical unattended station shows the arrangement of the apparatus which amplifies the signal and sends it on.

ON THE ROOF are the lens antennas, each with its horn tapering into a waveguide which leads down to equipment

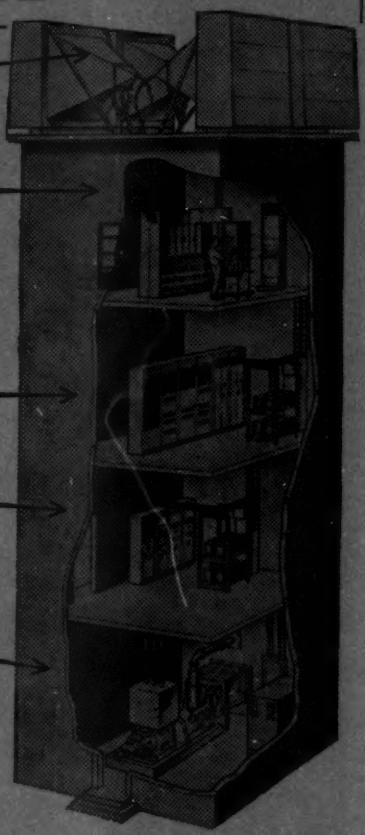
ON THE TOP FLOOR, where the signal is amplified, changed to a different carrier-channel and sent back to another antenna on the roof. Here are testing and switching facilities. Normally unattended, the station is visited periodically for maintenance.

ON THE THIRD FLOOR are the plate voltage power supplies for several score electron tubes.

ON THE SECOND FLOOR are filament power supplies. Storage batteries on both floors will operate the station in an emergency for several hours, but

ON THE GROUND FLOOR is an engine-driven generator which starts on anything more than a brief power failure.

Anything that happens—even an opened door—is reported to the nearest attended station instantly.



Coast-to-coast *Radio-Relay* shows again how scientists at Bell Telephone Laboratories help your telephone service to grow steadily in value to you and to the nation.

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